

## JSC/EC5 Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** Exploration of Mars with the ChemCam LIBS Instrument and the Curiosity Rover

**Date:** October 25, 2016

**Time:** 1:00 p.m. – 2:00 p.m.

**Location:** JSC/B29/CR 118

**DAA 1676 Form #: 37620**

This is a link to the recording of the lecture material <\\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY17 Knowledge Capture\20161025 SIPI Newsom MSL\1676 - Charts>

### **Assessment of Export Control Applicability:**

This presentation has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to the NASA Technical Library and Scientific and Technical Information (STI) Program for distribution through NASA's Technical Report Server (NTRS) (public or non-public) and YouTube viewing.

**Presenter:** Dr. Horton E. Newsom

**Synopsis:** The Mars Science Laboratory (MSL) Curiosity rover landed on Mars in August 2012, and has been exploring the planet ever since. Dr. Horton E. Newsom will discuss the MSL's design and main goal, which is to characterize past environments that may have been conducive to the evolution and sustainability of life. He will also discuss Curiosity's science payload, and remote sensing, analytical capabilities, and direct discoveries of the Chemistry & Camera (ChemCam) instrument, which is the first Laser Induced Breakdown Spectrometer (LIBS) to operate on another planetary surface and determine the chemistry of the rocks and soils.

**Biography:** Dr. Horton E. Newsom earned his undergraduate degree at the University of California Berkeley, and his doctorate at the University of Arizona, and is currently a senior research scientist and research professor within the Institute of Meteoritics and Department of Earth and Planetary Sciences at the University of New Mexico. He is a geologist and geochemist with more than 40 years of experience with planetary science, including the origin and composition of the Earth and Moon, and the study of terrestrial impact craters around the world and their hydrothermal systems. He has extensively studied surface processes on Mars including impact craters, sedimentary deposits, and phyllosilicate (clay) bearing terrains. He has also studied the origin and chemistry of Martian surficial materials using data from the Mars Odyssey Gamma Ray spectrometer experiment. Dr. Newsom has been involved with landing site selection for several Mars missions, including the Mars Exploration Rover (MER), Mars Science Laboratory (MSL), and future human landing sites. He is a co-investigator and science team member on the ChemCam Laser Induced Breakdown Spectroscopy (LIBS) instrument on the MSL "Curiosity," currently investigating habitable terrains on Mars. Dr. Newsom is actively involved with the daily operations of Curiosity, including planning science observations, and publication of the results. Dr.

Newsom is also responsible for advisement of undergraduate, graduate, and postdoctoral student research, and has been extensively involved in NASA-funded educational outreach to K-12 teachers, and to local middle school and high school students, and Native American colleges.

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# CURIOSITY

The Exploration of Mars With the ChemCam LIBS  
Instrument and the Curiosity Rover



NASA/JPL-Caltech/MSSS



Horton Newsom, Univ. of New Mexico,  
MSL Science Team, 10/25/2016

Mars is smaller than Earth and farther away from the sun –  
but Mars is the planet most like the Earth



Earth – one day is 24 hours 0 minutes



Mars – one day is 24 hours  
37 minutes.



## Operational 2001-2007



MER (1 still going)

2009

2011

2013



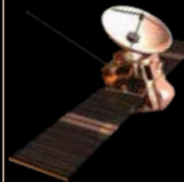
MAVEN  
Aeronomy  
Orbiter



India -  
Mangalyaan  
orbiter

2016

ESA—Russia  
ExoMars  
Trace  
Gas Orbiter



ESA—EDL  
Demonstrator



2018

Space-X -  
Red Dragon?



InSIGHT  
geophysical  
lander



2020

China -  
orbiter/rover?

UAE-Hope  
Orbiter



Mars 2020 —  
sample caching

ESA-Russia  
Rover: ExoMars



2022 &  
beyond



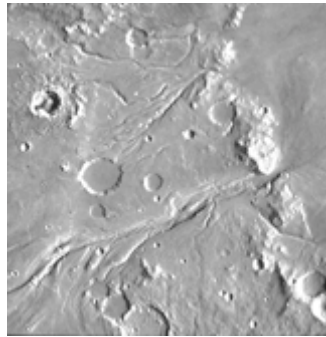
Mars sample  
return



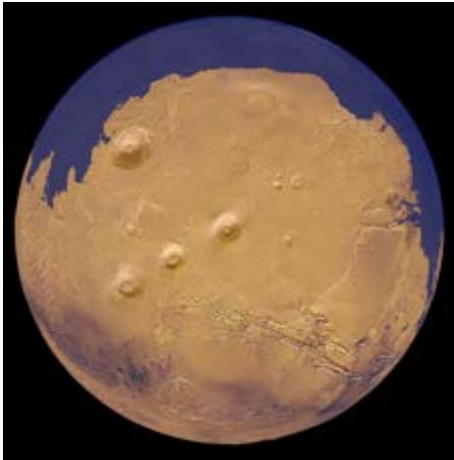
# Ancient Features Indicate Abundant, Stable Water



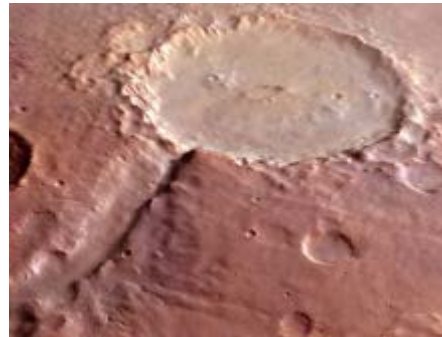
valley networks



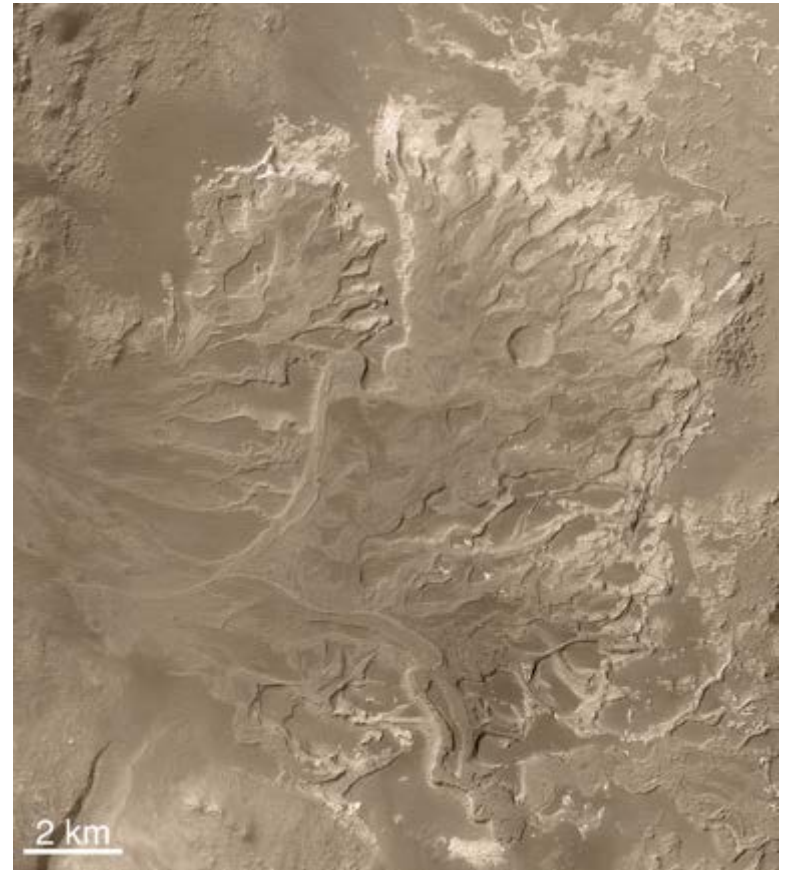
outflow channels



possible shoreline of ancient northern ocean



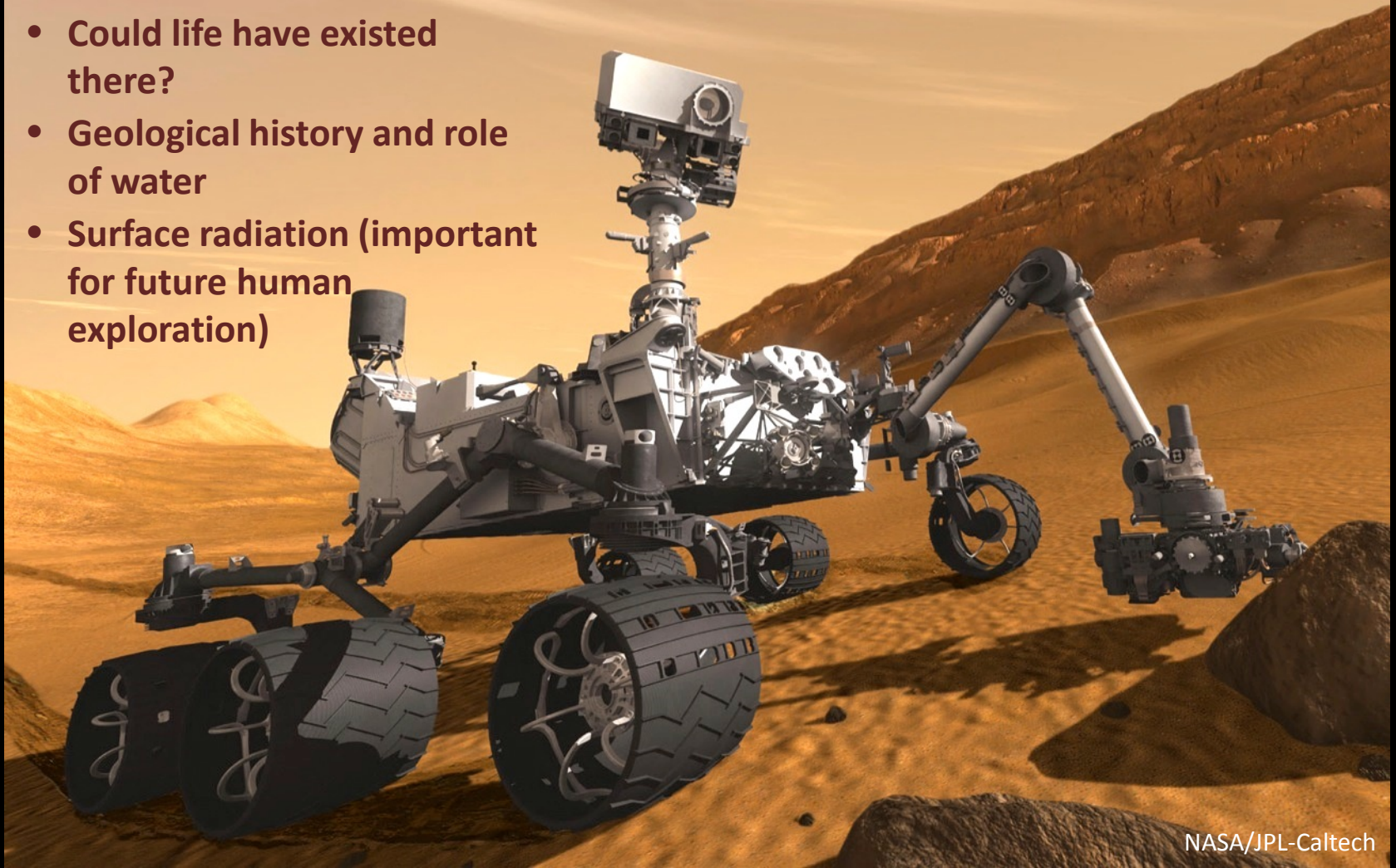
crater lakes



deltas

Curiosity's primary scientific goal is to explore a local region on Mars' surface as a potential habitat for life, past or present

- Could life have existed there?
- Geological history and role of water
- Surface radiation (important for future human exploration)



NASA/JPL-Caltech



## Curiosity's Science Objectives

# How to get to Mars?

6 years of construction,  
launch November 26, 2011,  
8 months travel to Mars,  
landing August 6, 2012

# CONSTRUCTION

- **Brains:** Computers, chips, gates etc to process information.
- **Base:** A base or body for supporting all the other parts of the robot.
- **Eyes and other "senses":** Sensors that give information about environment.
- **Arm:** A way to extend its reach.
- **Legs with wheels:** Parts for mobility.
- **Energy:** Batteries and power.



NASA/JPL-Caltech



## Building Curiosity

# Curiosity is big!

This is the twin of Curiosity (called the test-bed) used on Earth to test how to use Curiosity

At the test-bed rover during Operational Readiness Test in March 2012

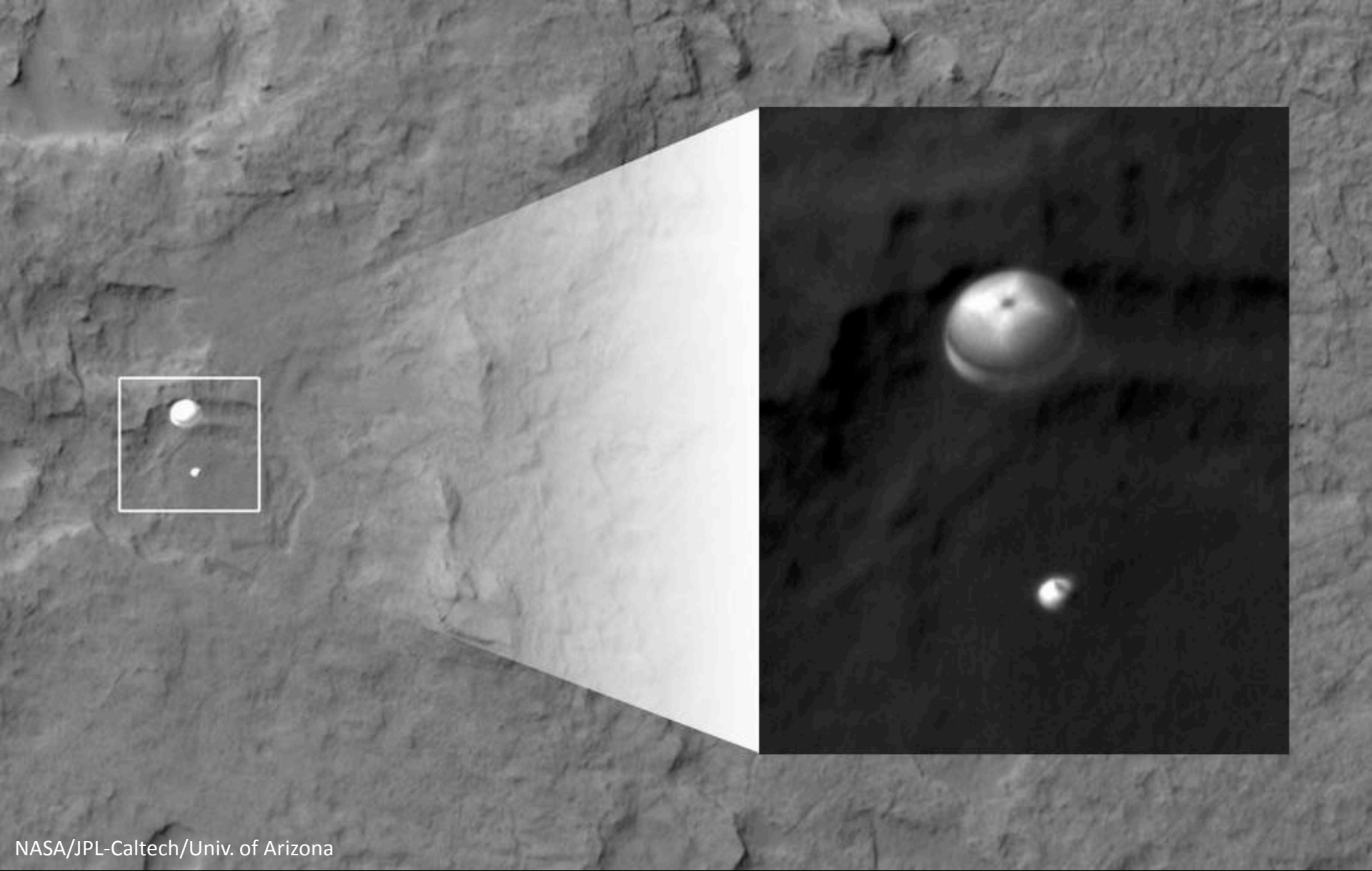


Nov. 26, 2011...



Launch from Florida – Atlas 5, 190 feet high!





NASA/JPL-Caltech/Univ. of Arizona



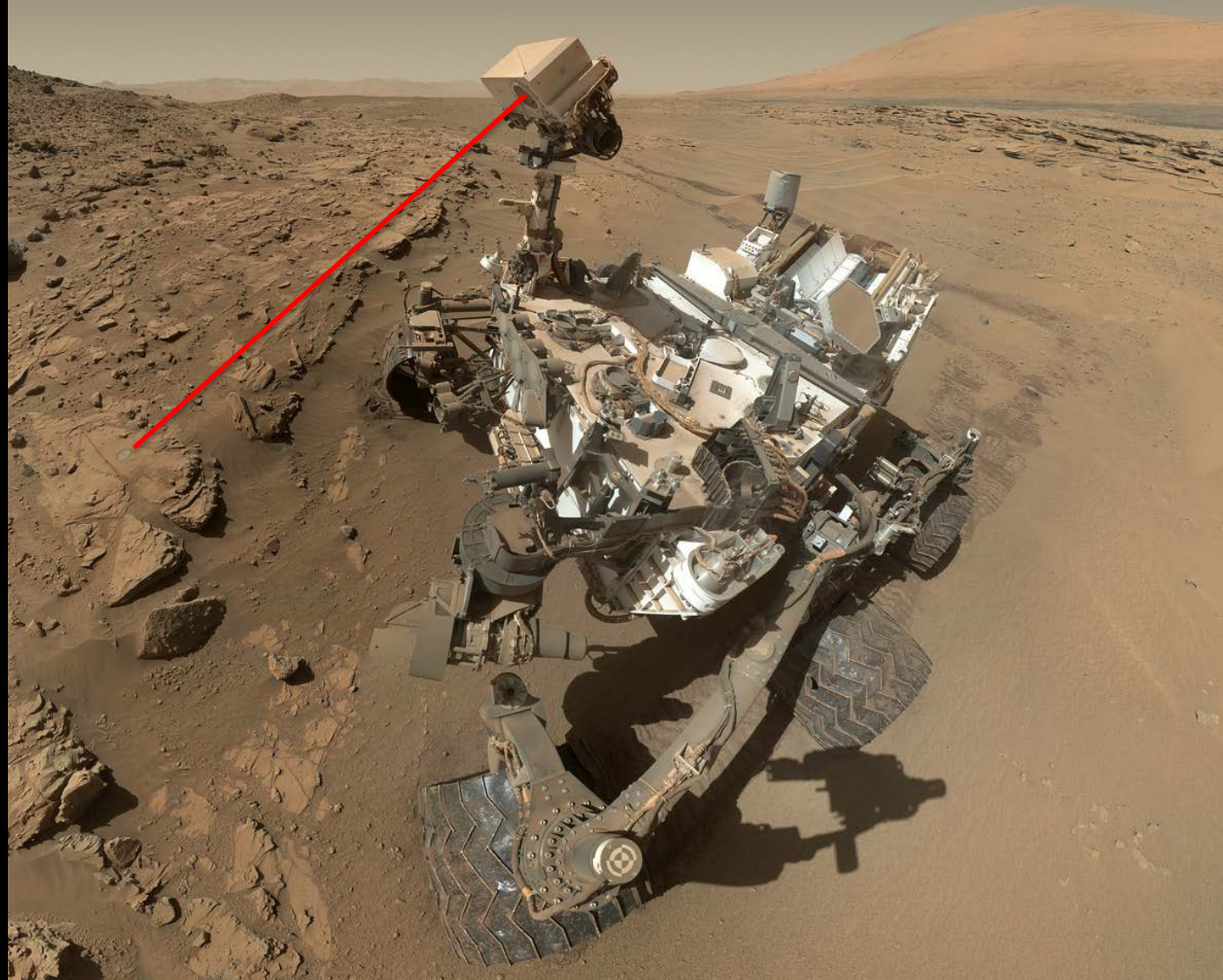
**Curiosity during landing on parachute, imaged by HiRISE on the Mars Reconnaissance Orbiter satellite**

# Curiosity at the Kimberley



# Curiosity at the Kimberley

What ChemCam does!



# Curiosity Rover

**Remote**

**ChemCam**  
(Chemistry)

**Mastcam**  
(Imaging)

**REMS**  
(Weather)

**DAN**  
(Hydrogen)

**RAD**  
(Radiation)

**Contact**

**MaHLI**  
(Imaging)

**APXS**  
(Chemistry)

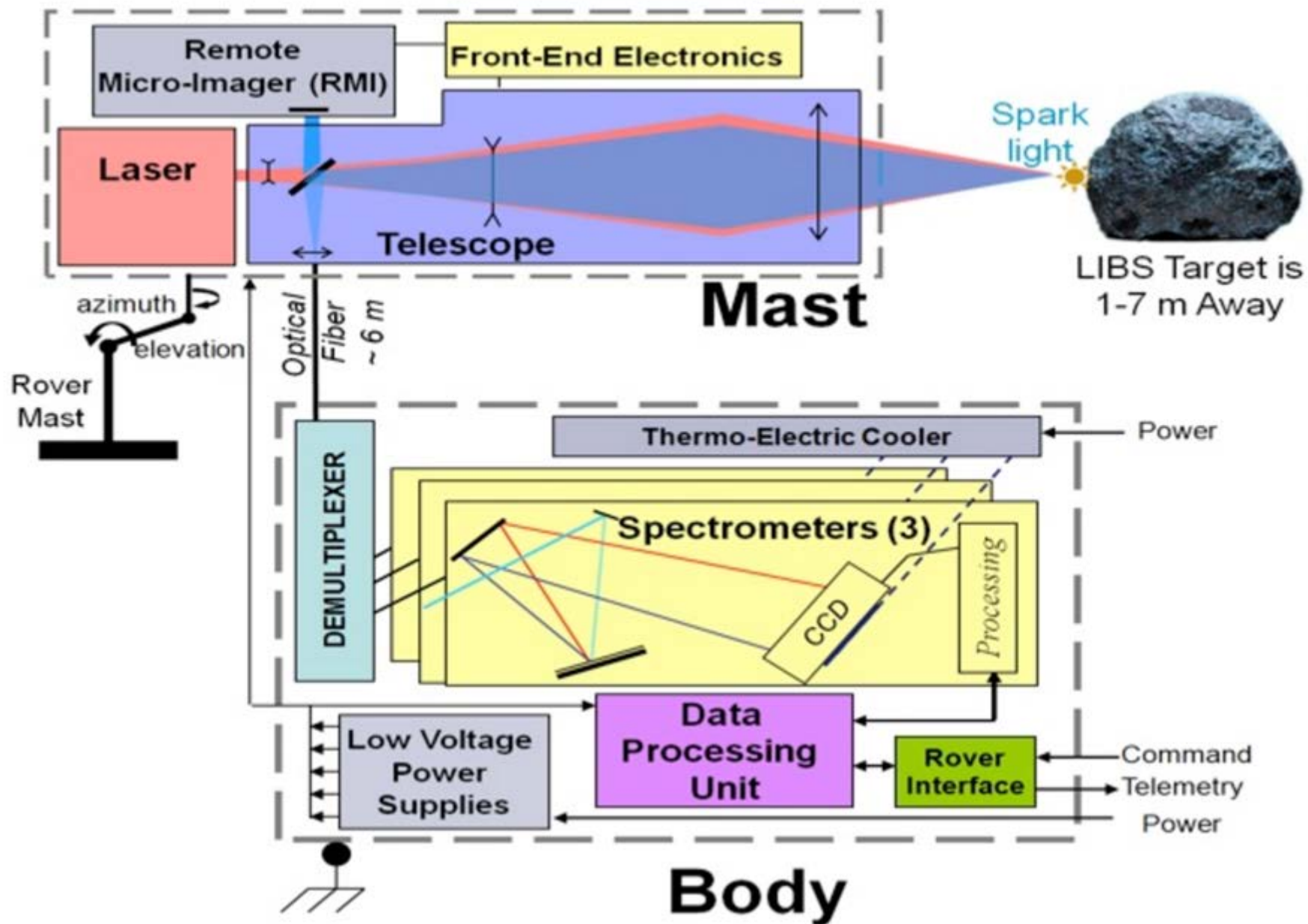
**In-Situ**

**SAM**  
(Isotopes)

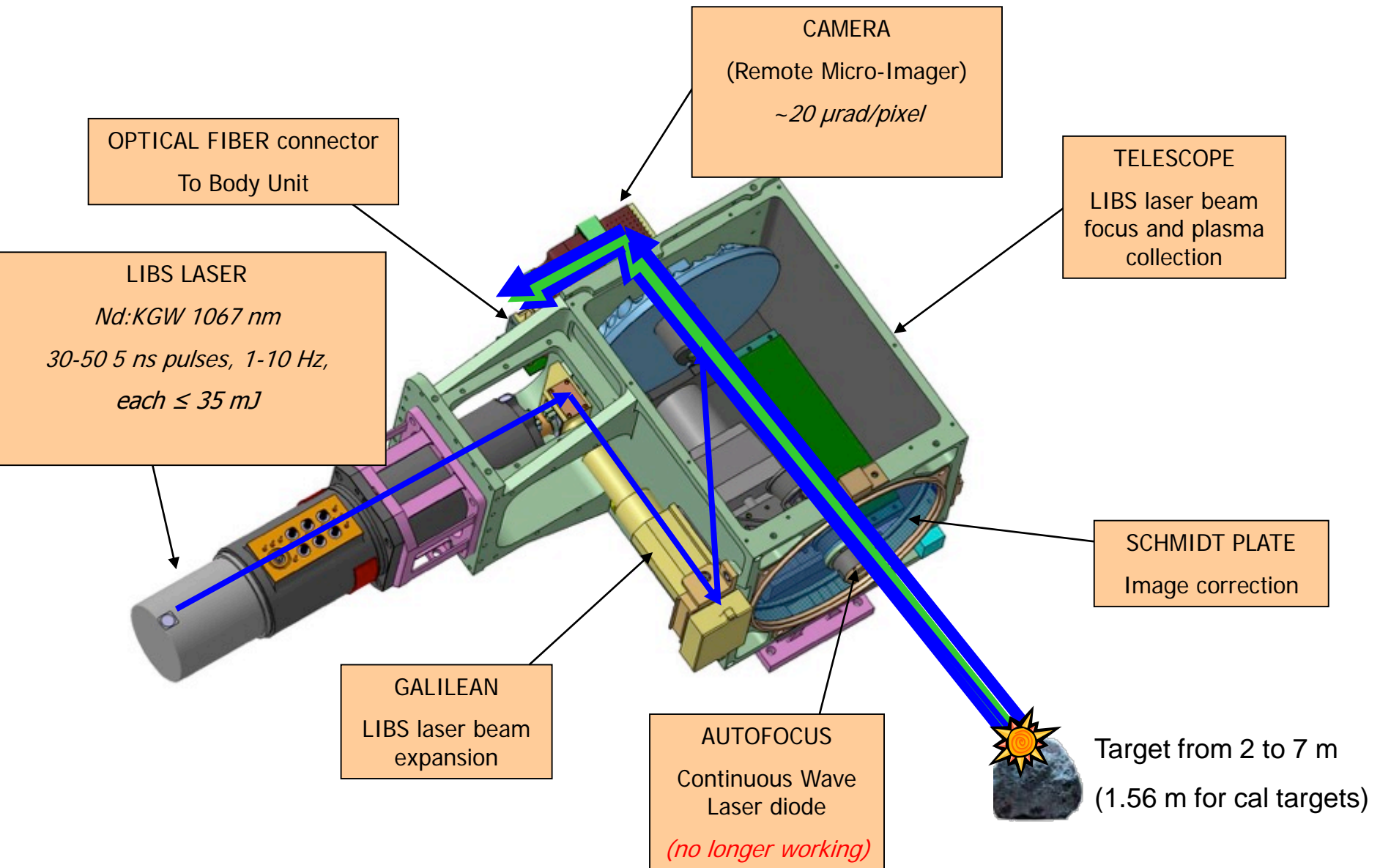
**CheMin**  
(Mineralogy)

**MARDI**  
(Imaging)

# ChemCam Block Diagram

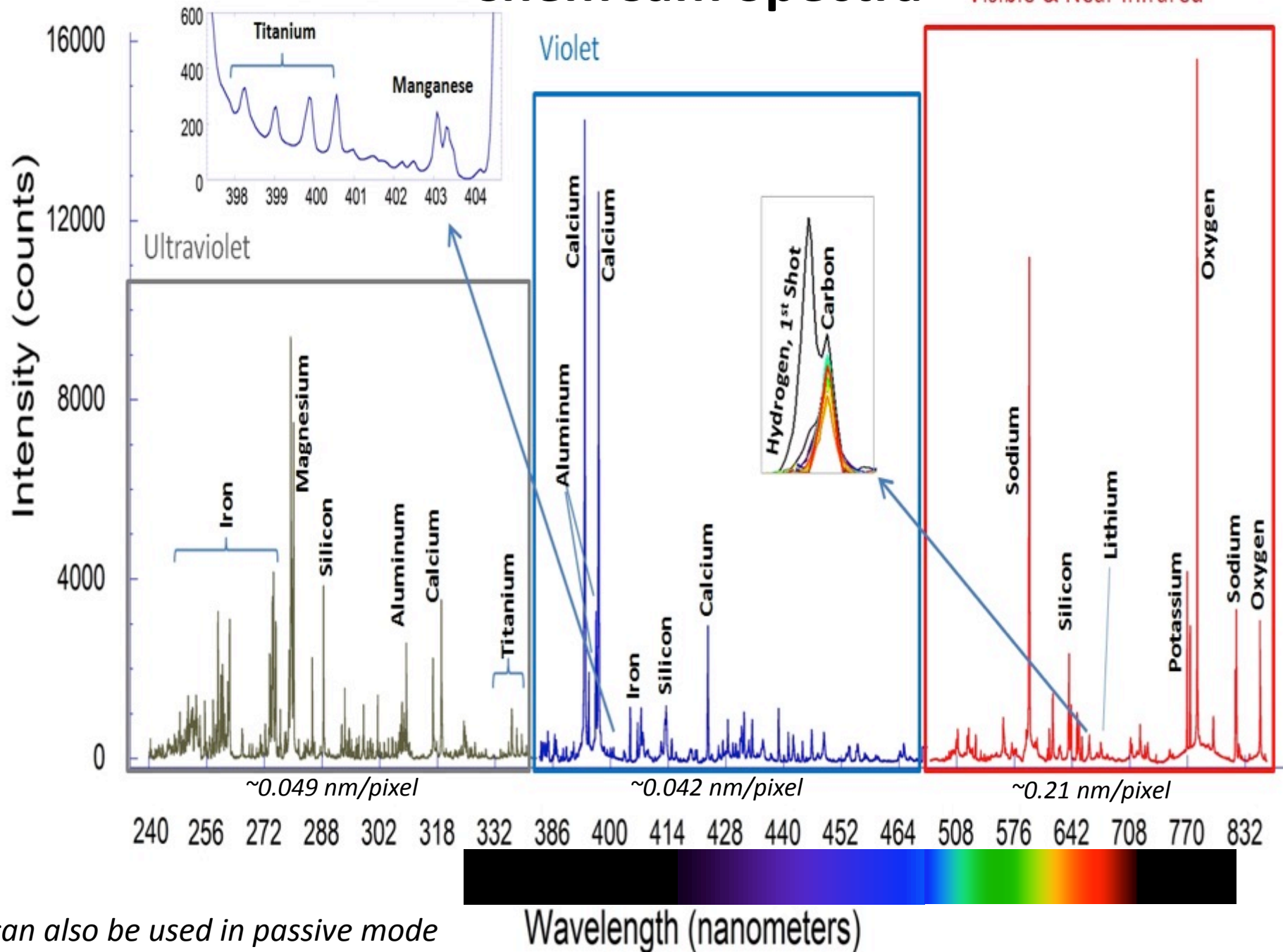


# ChemCam Mast Unit: Optical Box



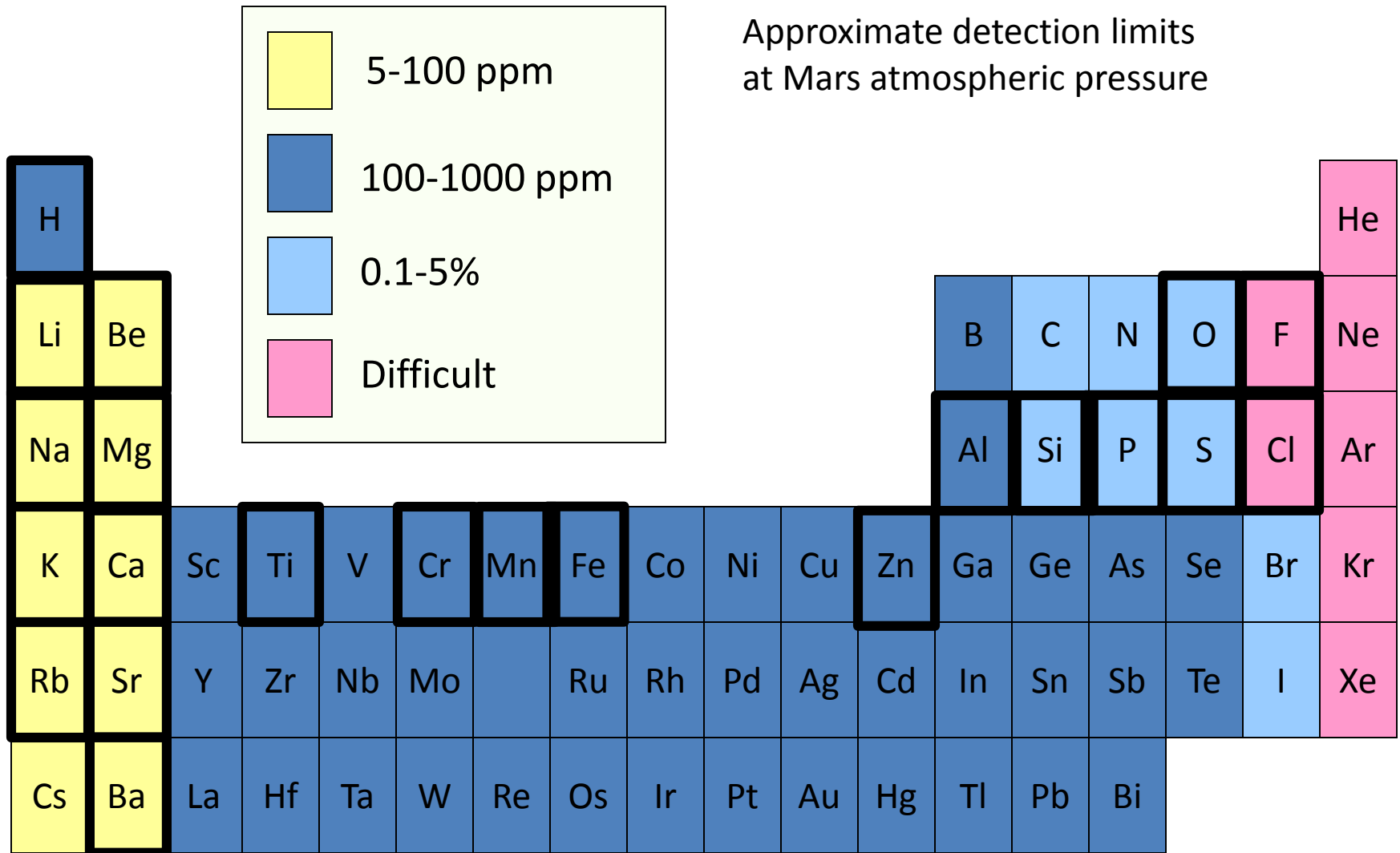
# ChemCam Spectra

Visible & Near Infrared

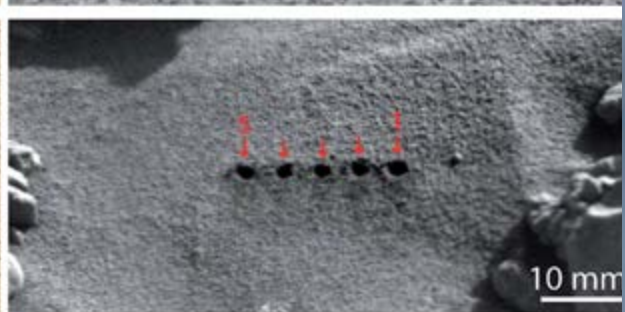
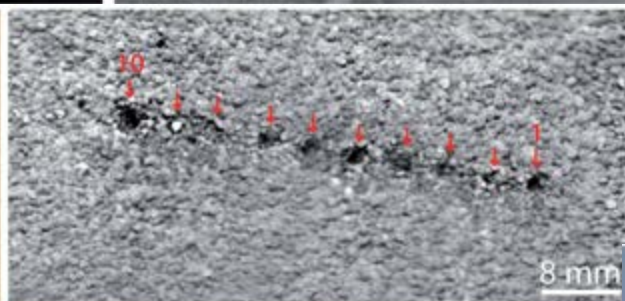
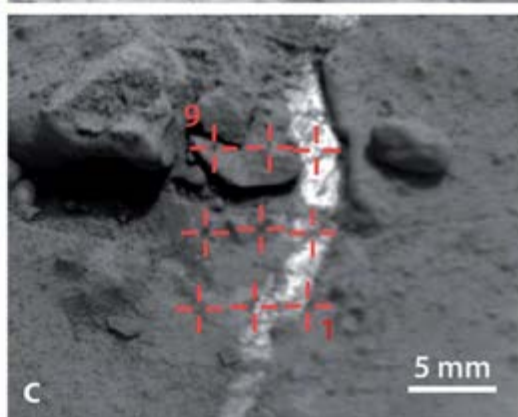
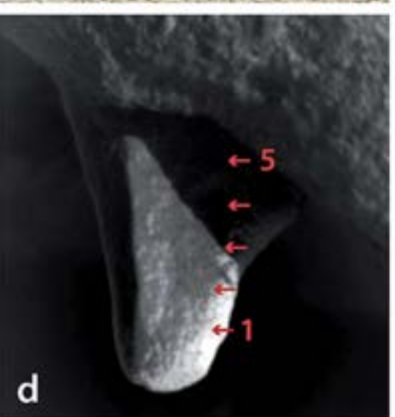
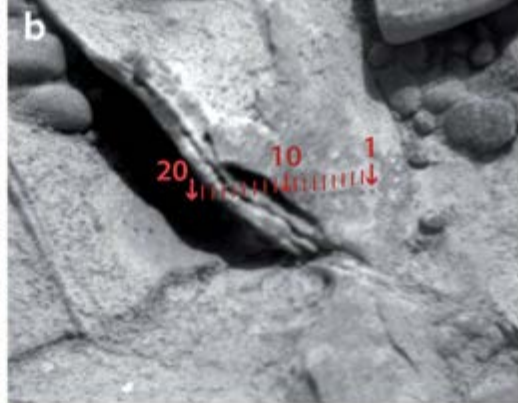
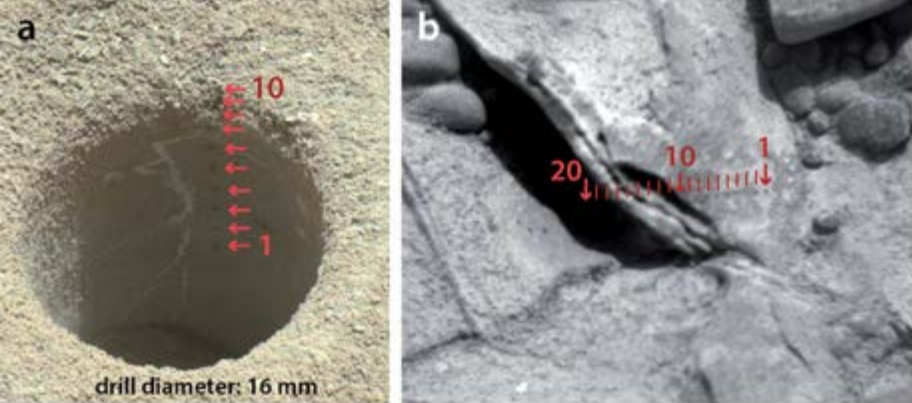


can also be used in passive mode

# LIBS Sensitivities, ChemCam Configuration



Observed on Mars so far



Pointing: Accuracy is  $\pm 2$  mrad (4-14 mm), but precision (between points) is much finer

### Points

Size is  $\sim 0.3$ - $0.6$  mm

Each consist of 30-50 shots

- depth profile,  $\sim 100$   $\mu$ m in rock, a few mm in soil

Commonly separated by 2 mrad

### Baseline Rasters

Line (horizontal, vertical, diagonal): 1x5, 5x1, 1x10, 10x1

Grid: 3x3, 5x5

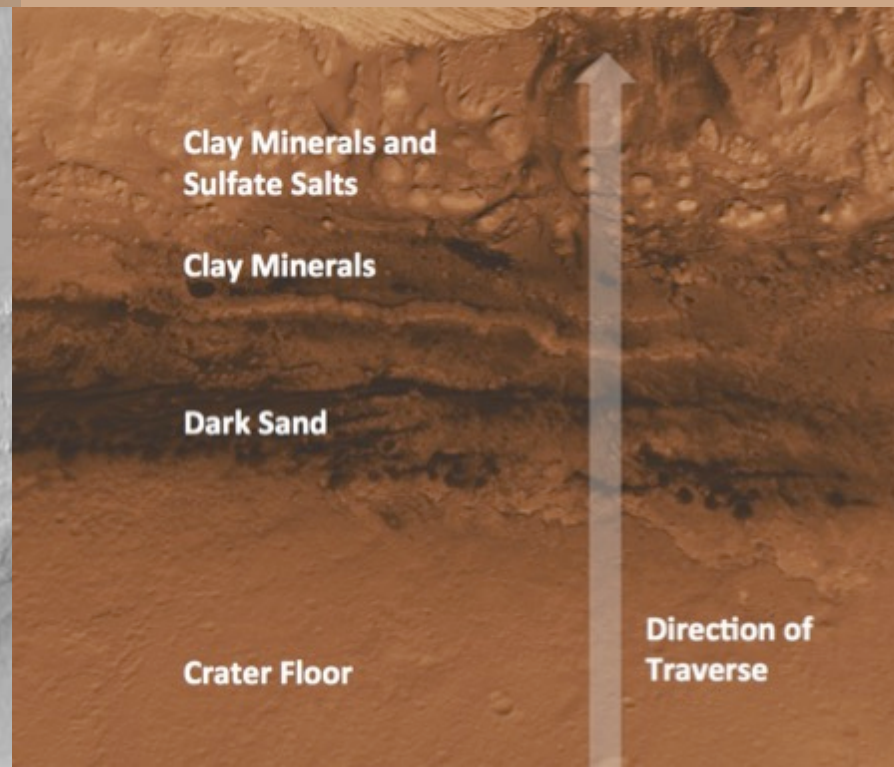
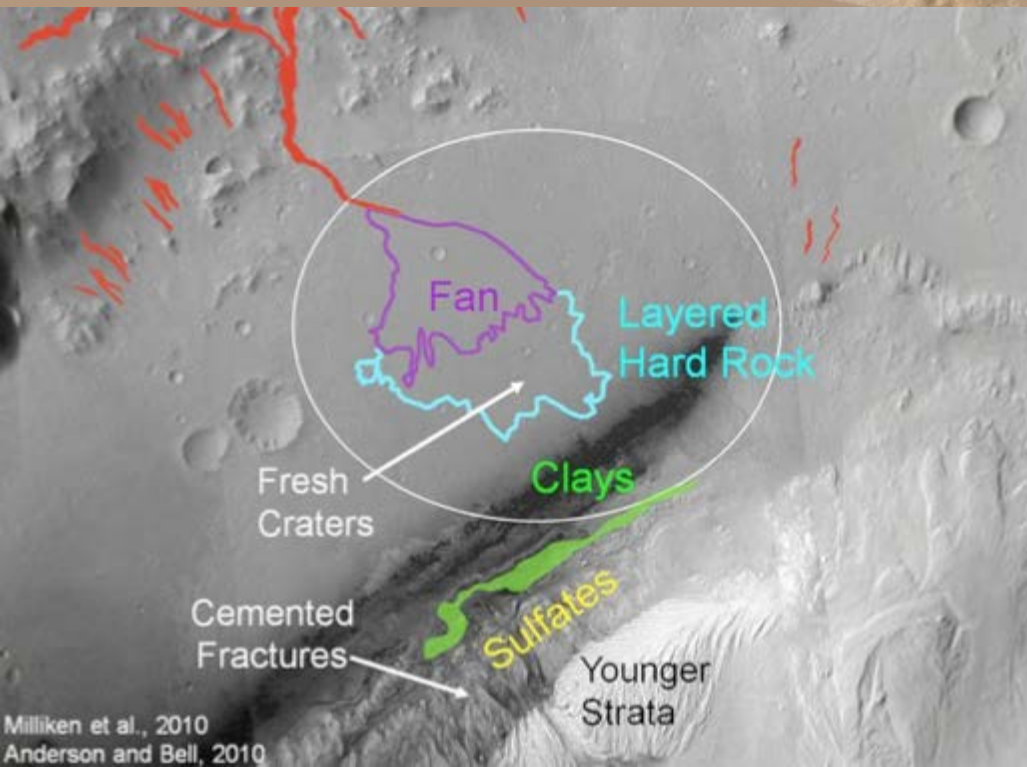
*Single point: 1x1 (generally calibration targets only)*



# Gale Crater



- Geologic potpourri for Mars
- Stratigraphic succession of sedimentary layers 5.5 km thick
- Geomorphology: Dried alluvial fans, channels, and deltas; sand dunes; yardangs



# Long Distance RMI Imaging



Target Green\_Head (sol284)



NavCam Left

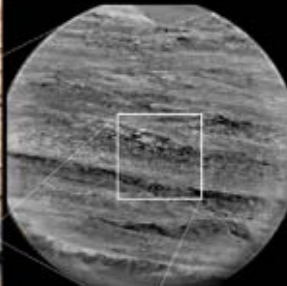


RMI Z-stack

Castle\_Mountain (sol 312)



MastCam 100 - sol 312



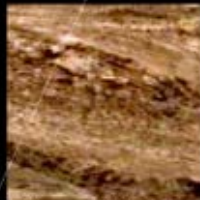
RMI  
(CR0\_435187380EDR)



Mastcam 100

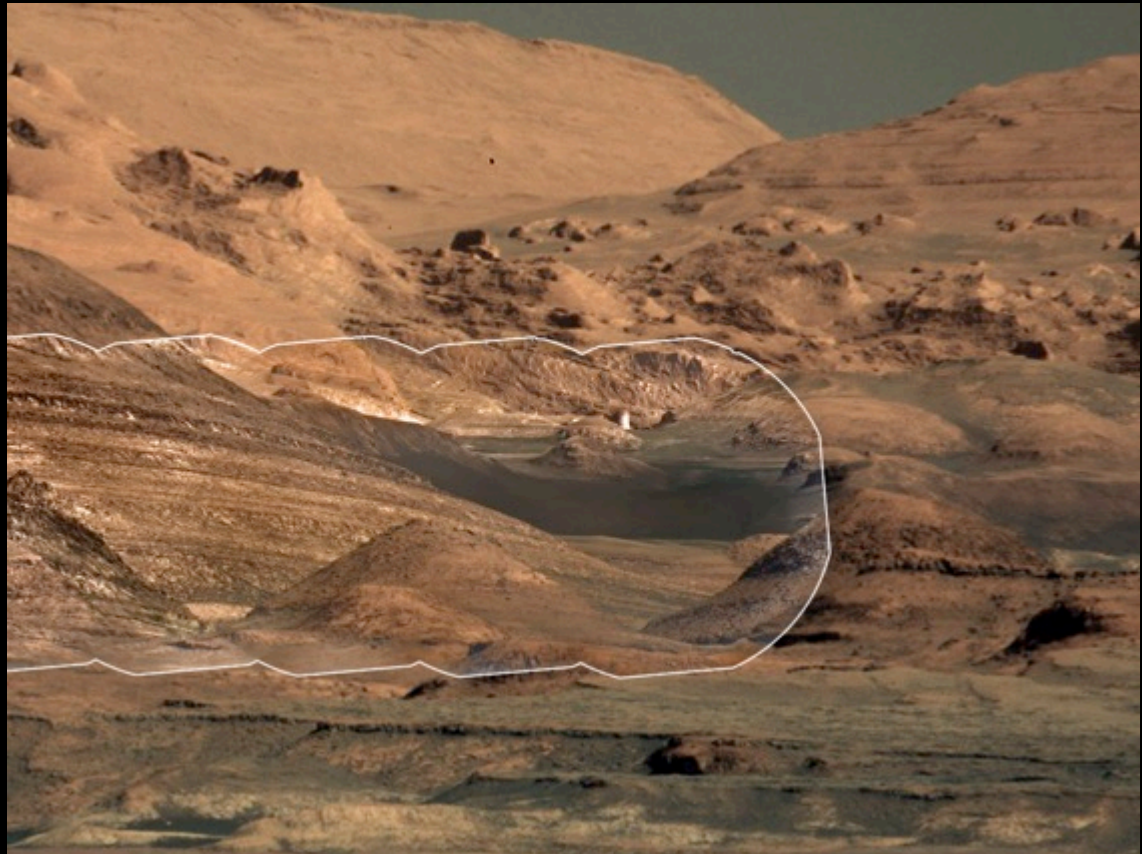


ChemCam/RMI

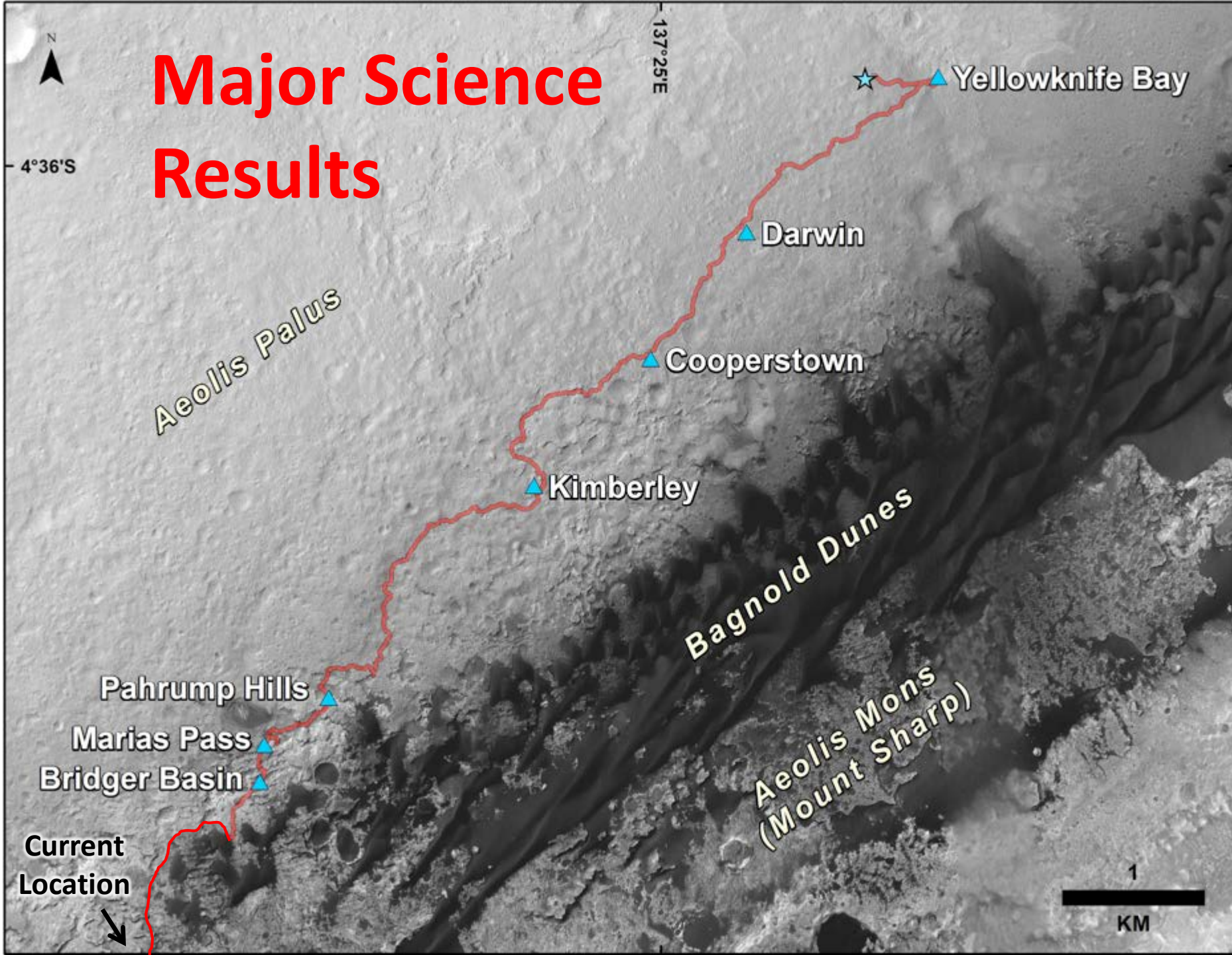


RMI merged with MastCam

With a pixel scale nearly 4x finer than Mastcam, ChemCam's Remote Micro-Imager can discern  $\sim 5\text{cm}$  objects 1 km away. It is very useful in assessing distant outcrops, dunes, and other features.

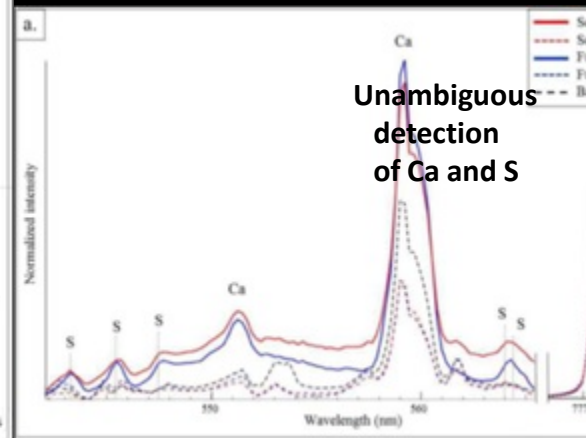
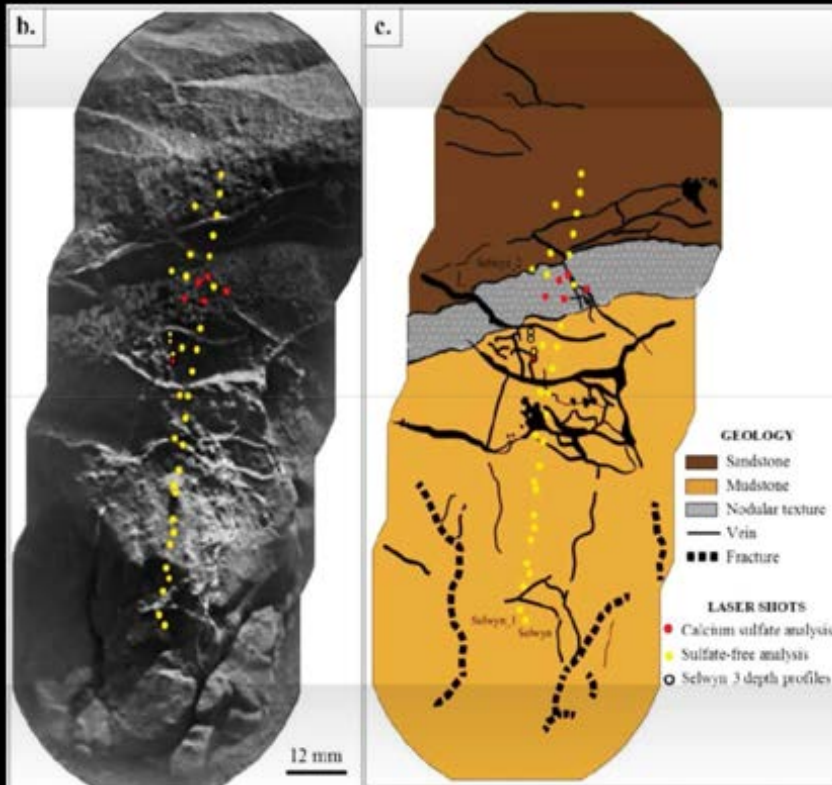


# Major Science Results

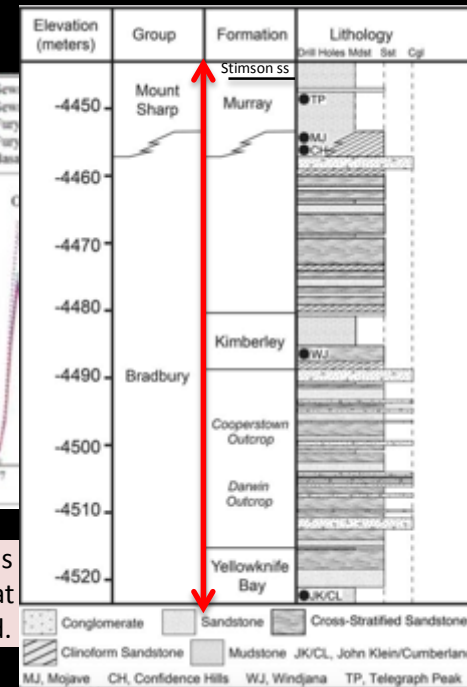




Calcium sulfate veins, of variable hydration, are in all the sedimentary rocks along MSL's traverse so far

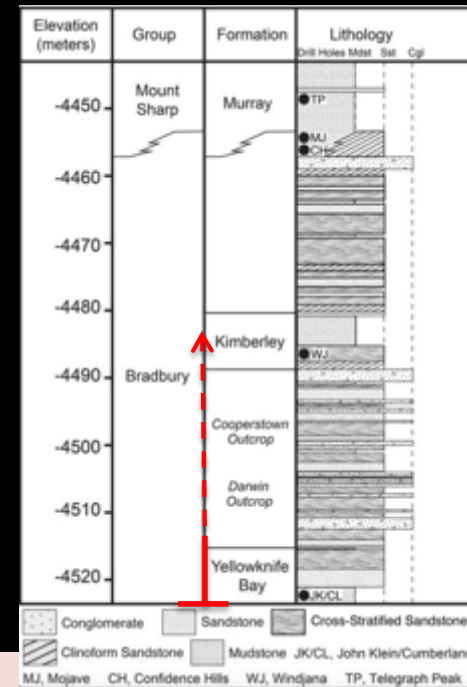
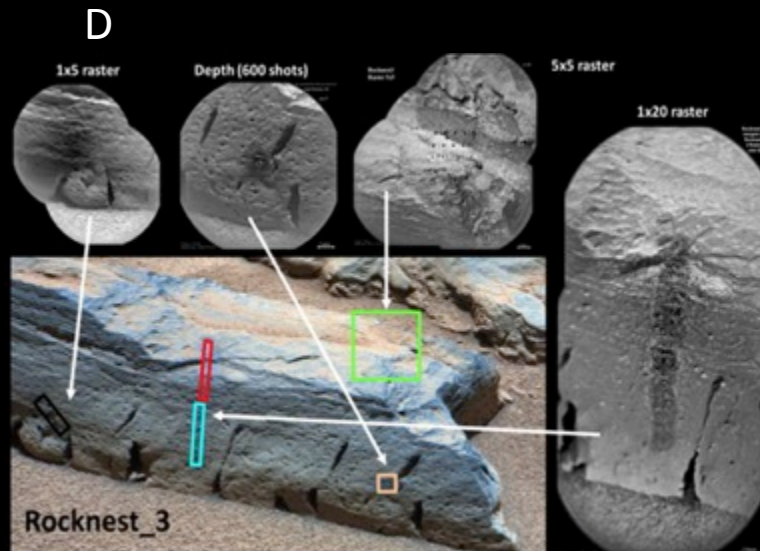
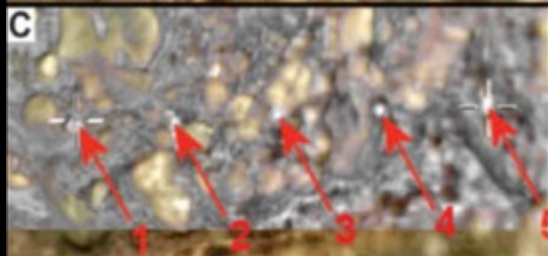
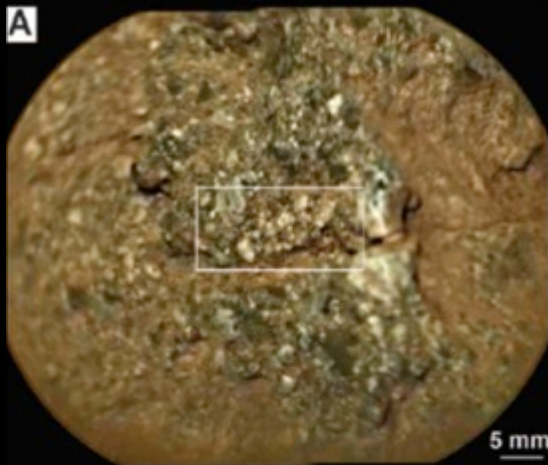


- Nachon M. et al. (2013) Calcium sulfate veins characterized by the ChemCam instrument at Gale crater, Mars. J. Geophys. Res., accepted.



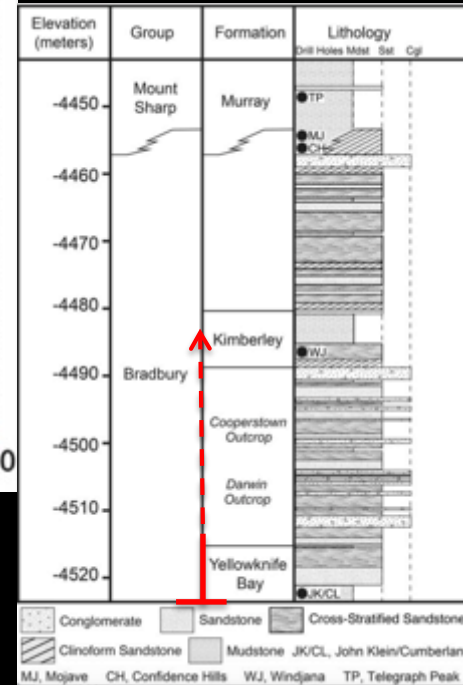
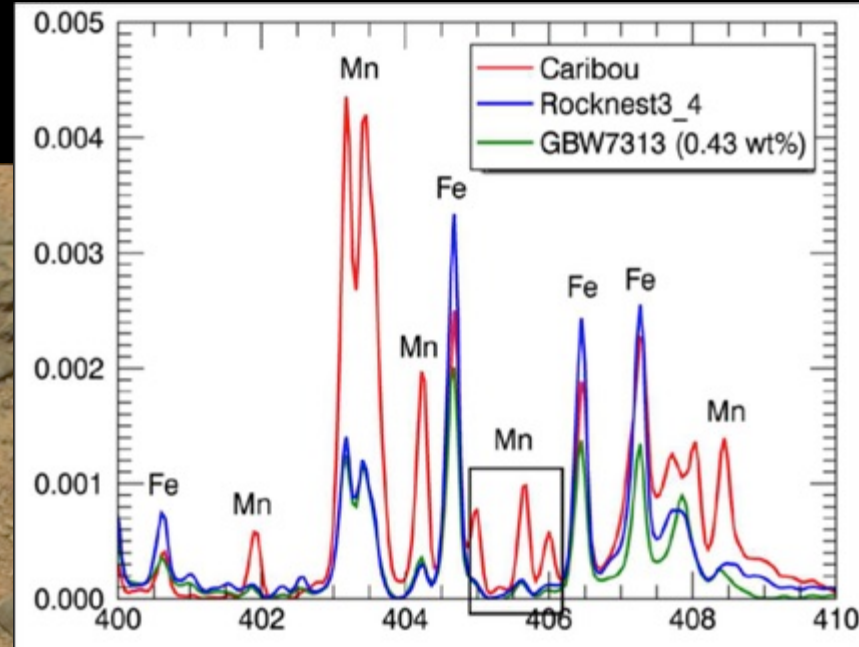
Chemostratigraphy with ChemCam laser

# Analysis of conglomerates shows strong evidence for iron-bearing cement.



- Williams R. et al. (2013) Martian fluvial conglomerates at Gale Crater. Science 340, 1068-1072, DOI: 10.1126/science.1237317.
- Blaney D. et al. (2013) Chemistry and texture of the rocks at "Rocknest", Gale crater: Evidence for iron-rich cements. J. Geophys. Res., submitted.

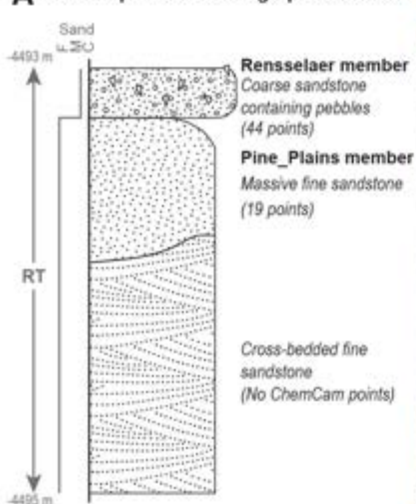
Manganese-rich compositions are found in some rocks, indicating a highly oxidizing environment, which currently does not exist on Mars



Caribou Sandstone with High-Mn Mineral

- Lanza N. et al. (2014, 2015)

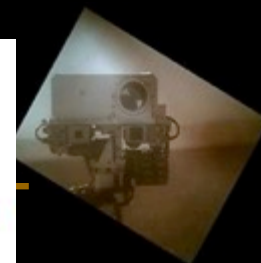
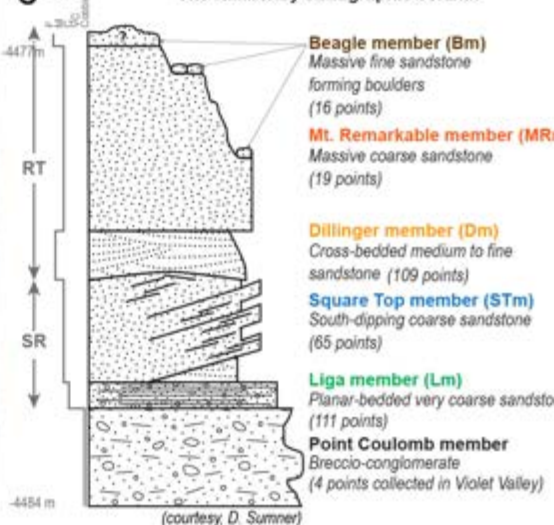
**A** The Cooperstown stratigraphic column



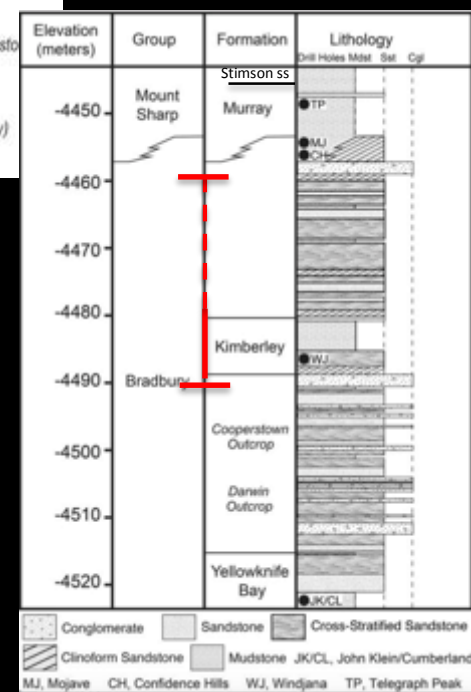
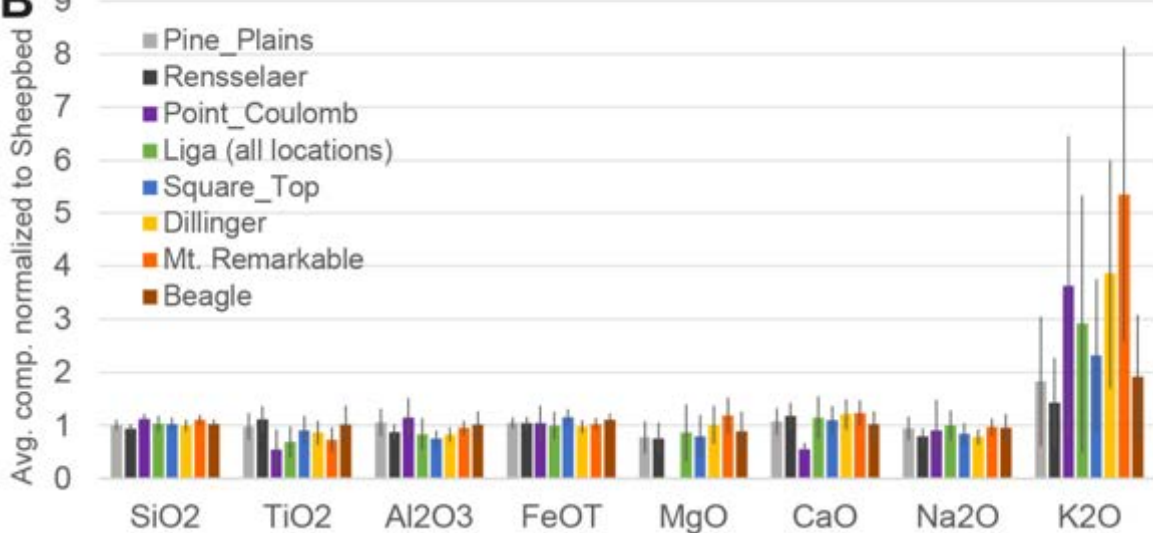
**B** The Kimberley (HIRISE IRB color image)



**C** The Kimberley stratigraphic column

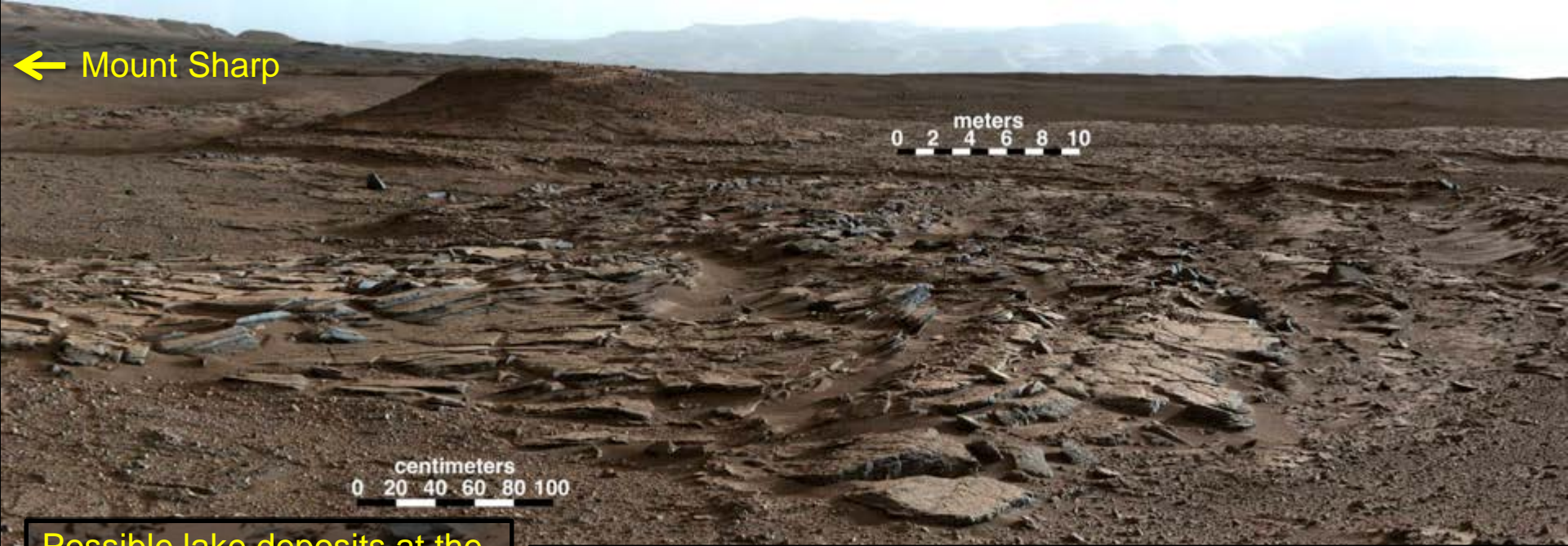


**B**

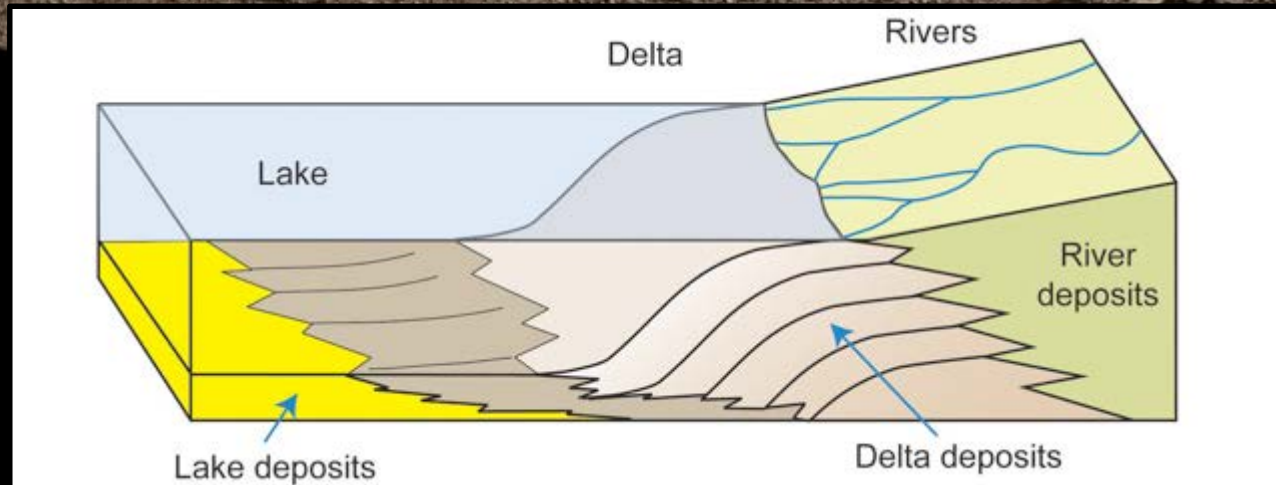


Potassic-rich sandstones, probably from a detrital source (low CAI index), are found in to increase upward within the Bradbury formation (strata below Mt. Sharp) [Le Deit et al., 2015]

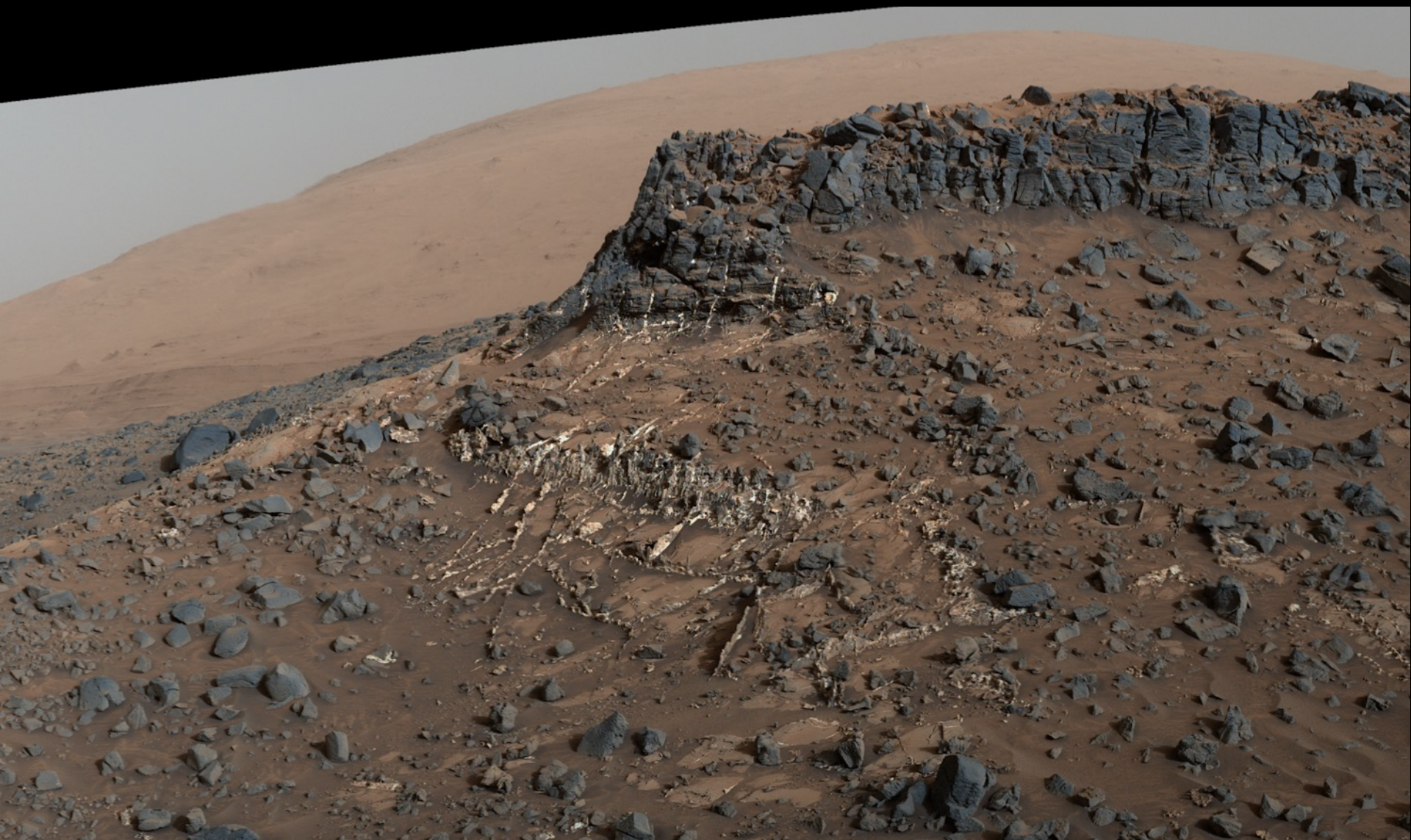
← Mount Sharp



Possible lake deposits at the base of Mount Sharp



**Curiosity discovered south-tilted sandstone beds on Gale Crater's plains that indicate water-driven transport of sediment, building lower Mount Sharp from lake deposits**



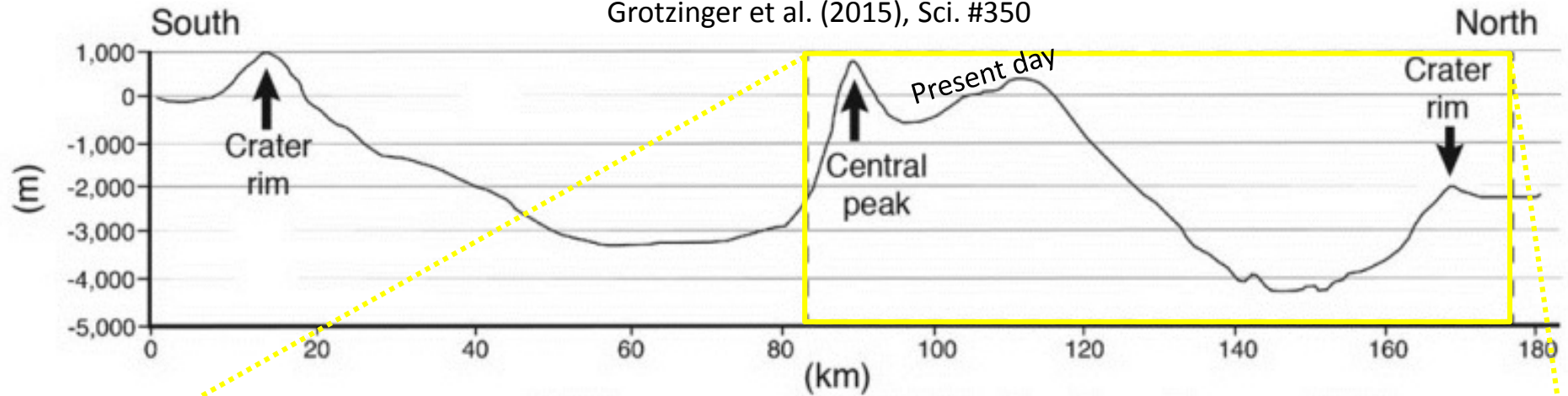
**Mineral veins of varying composition fill fractures within the lake-formed mudstone, indicating multiple generations of interaction with liquid water. ChemCam has been critical in the vein analyses.**



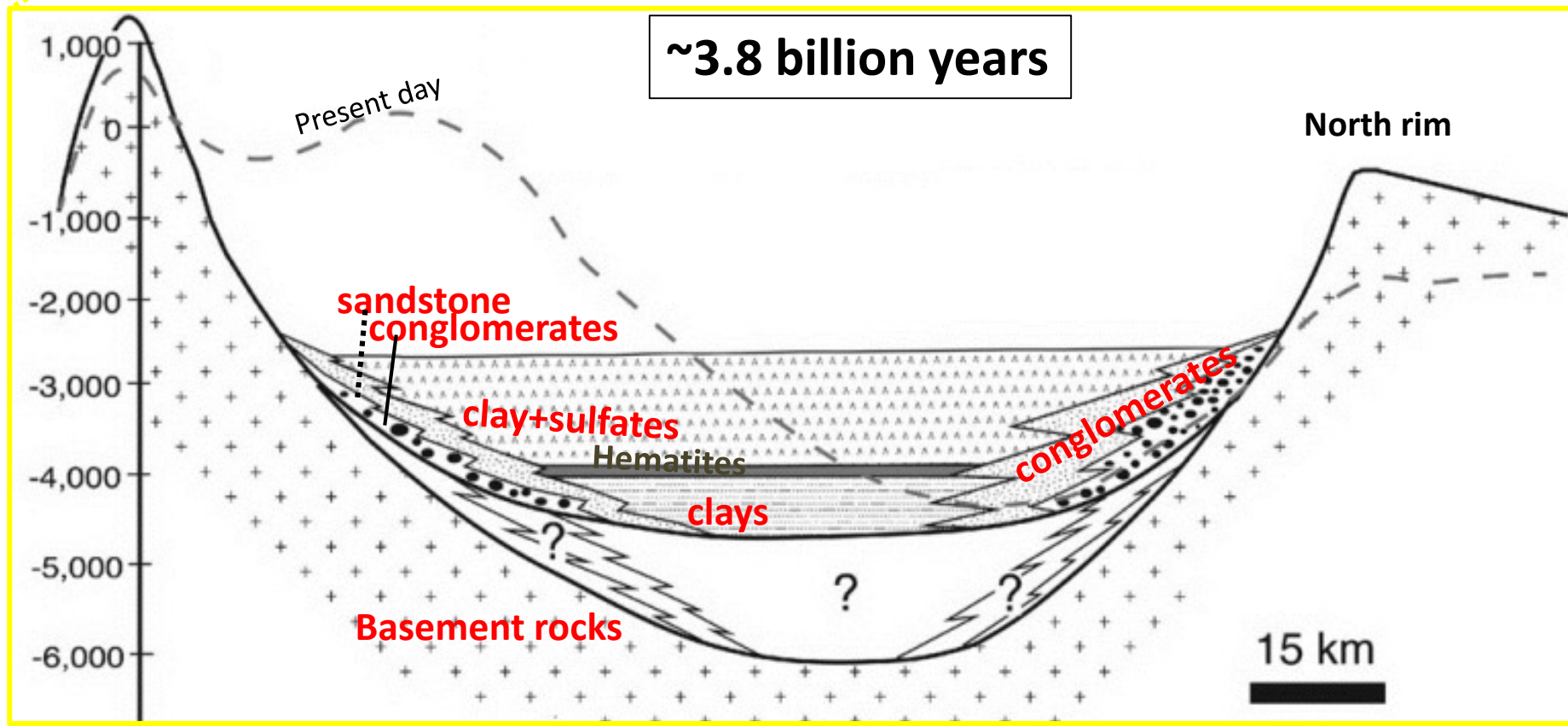
**At Marias Pass, Curiosity discovered significant enrichments of silica in the mudstone. The Buckskin drill sample contained amorphous silica as well as the mineral tridymite that likely originated from a silica-rich volcanic source.**

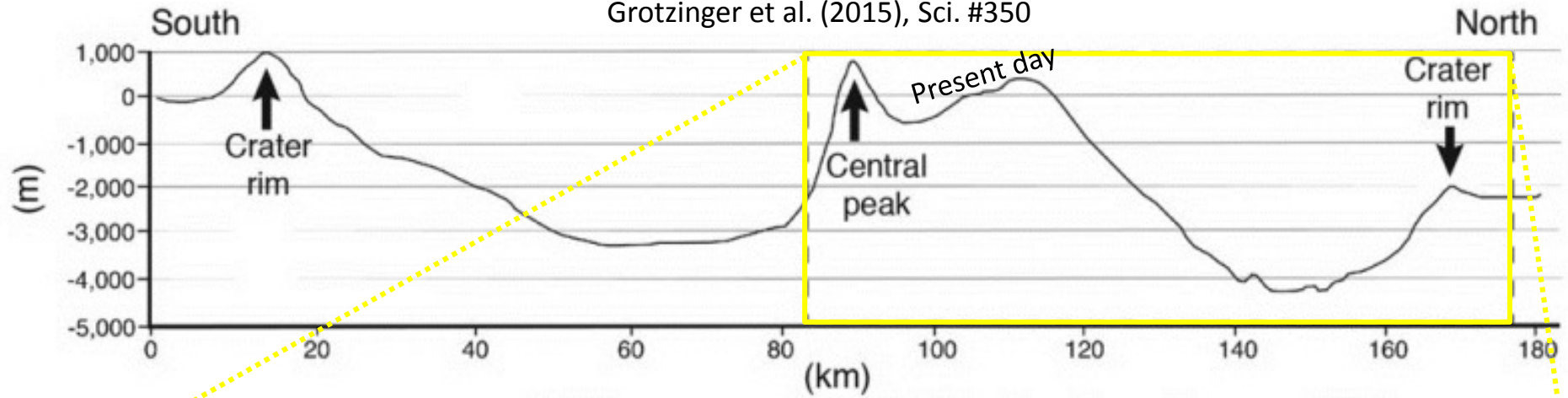
# **The Big Picture: What we now know about the changing sedimentary environment in Gale Crater and Mars in general**





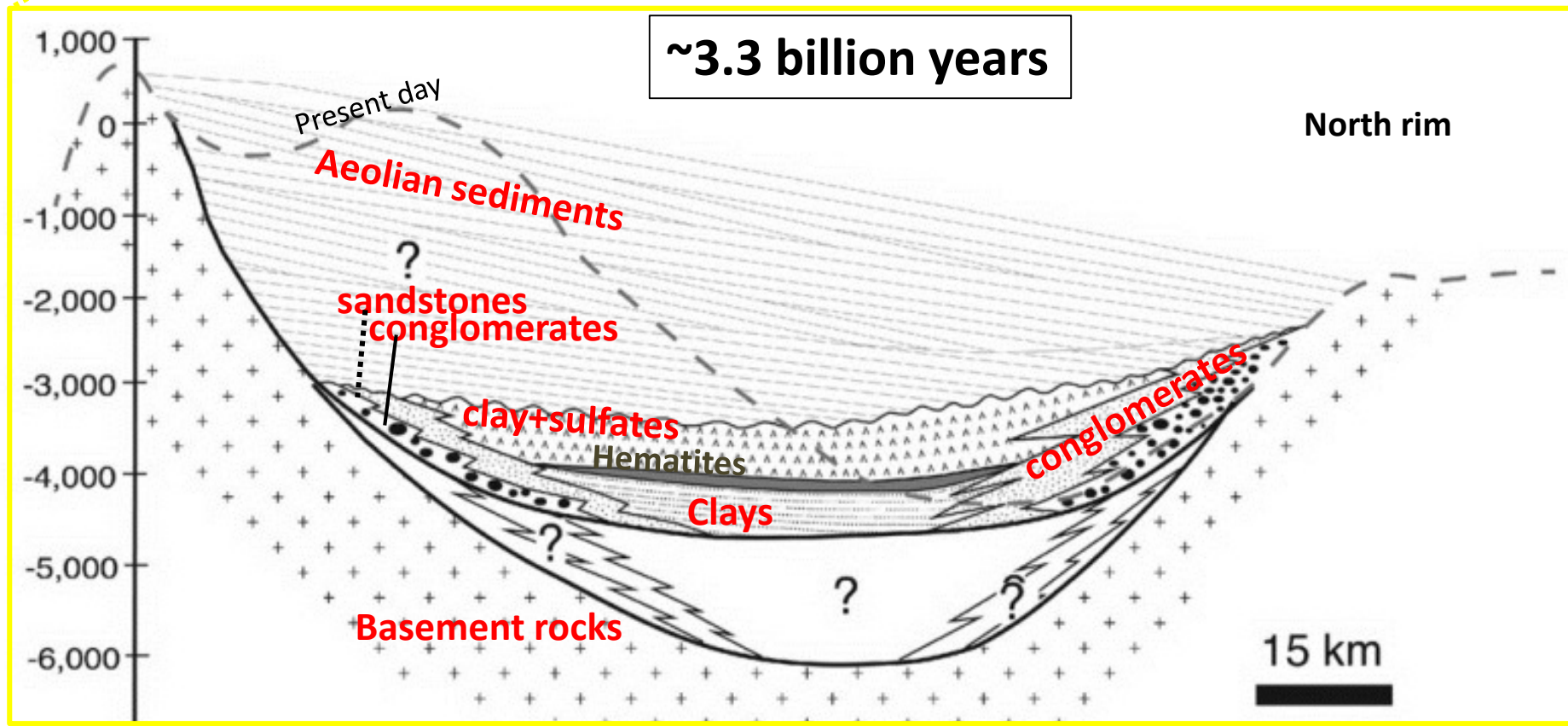
Central peak

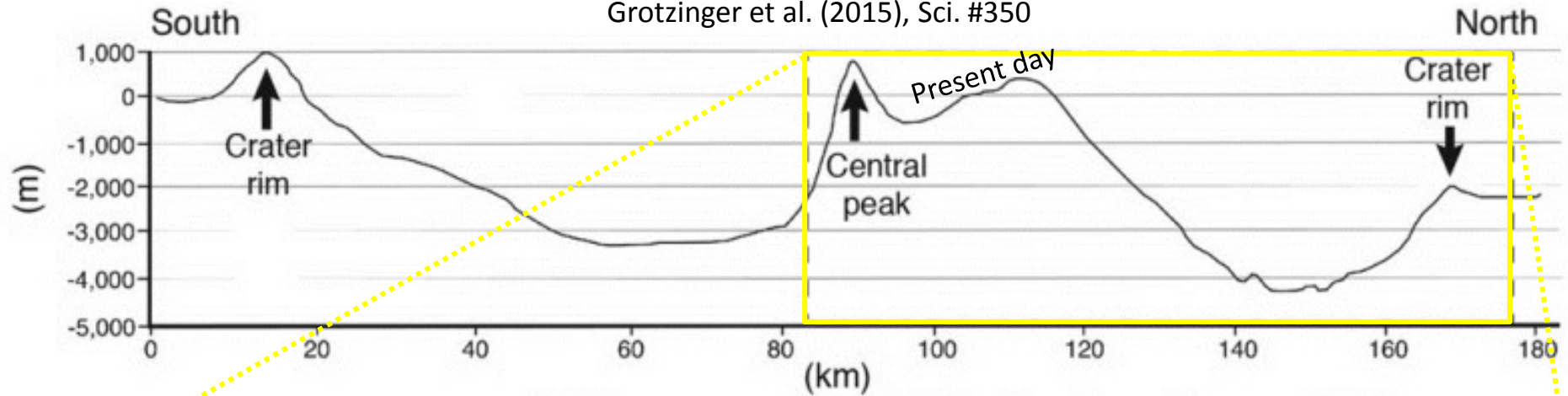




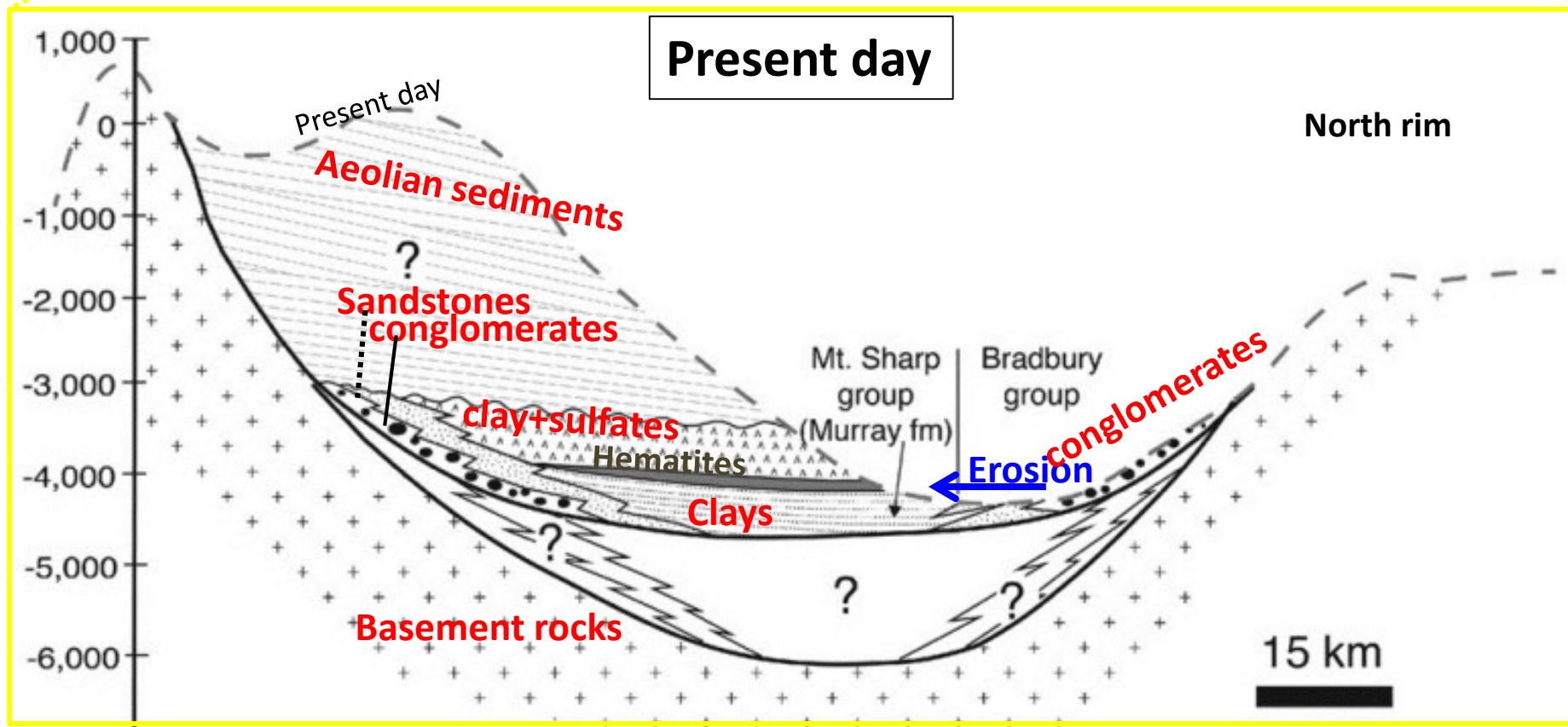
Central peak

Sloping rock beds





Central peak



clays (~5 mm)

clays (~10 mm)

Fluvial sandstones  
(transport rt to left)

conglomerates

Present day

Aeolian sediments

Sandstones  
conglomerates

clay+sulfates

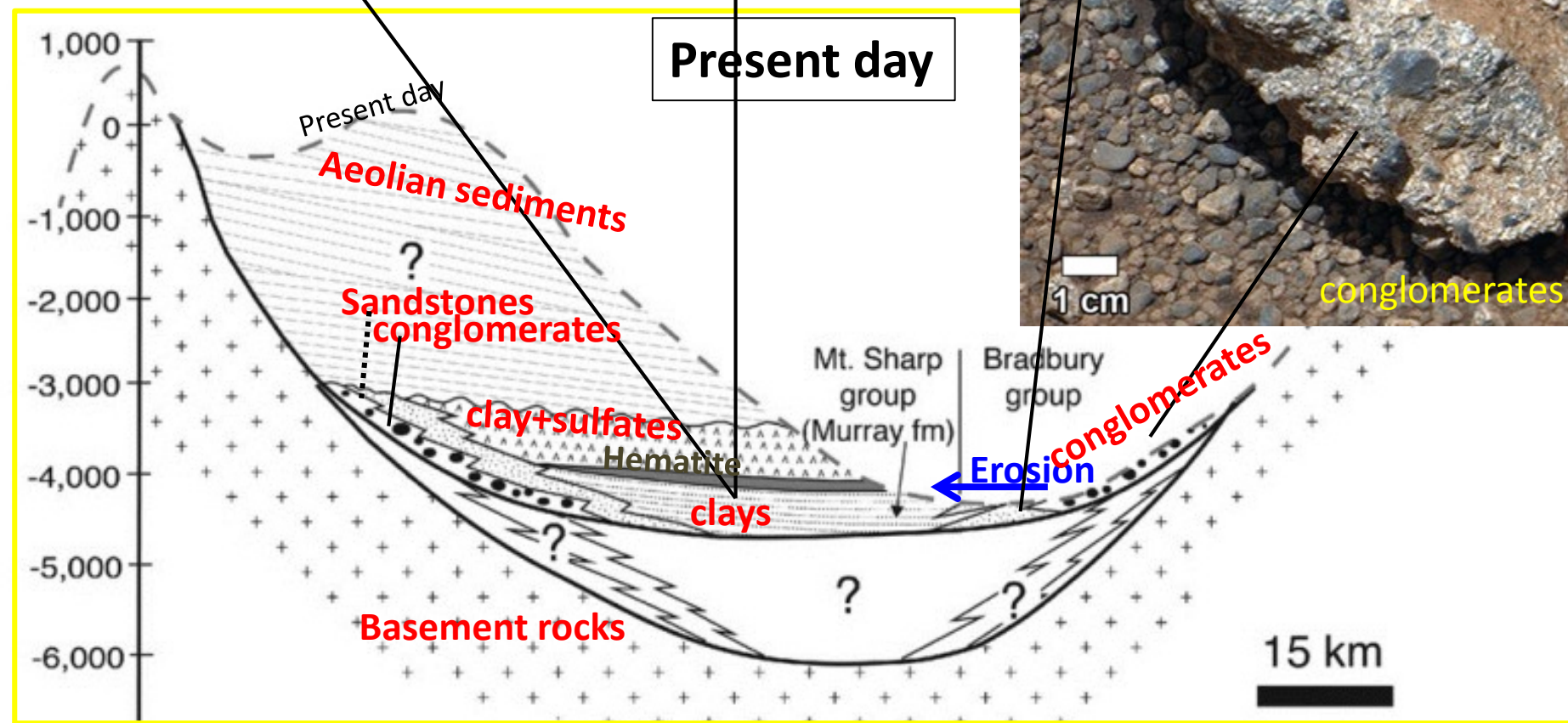
Hematite

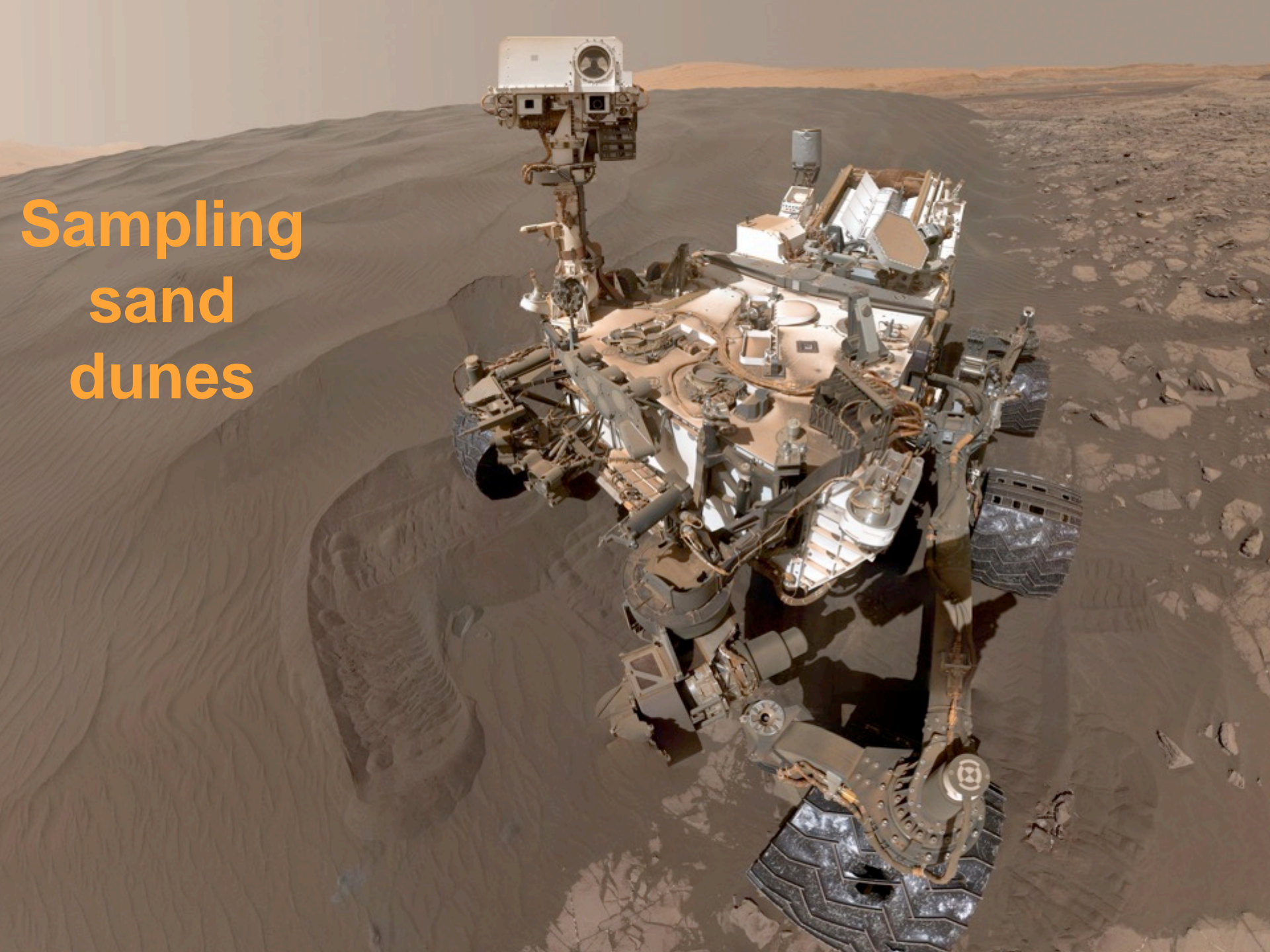
clays

Erosion

conglomerates

Basement rocks

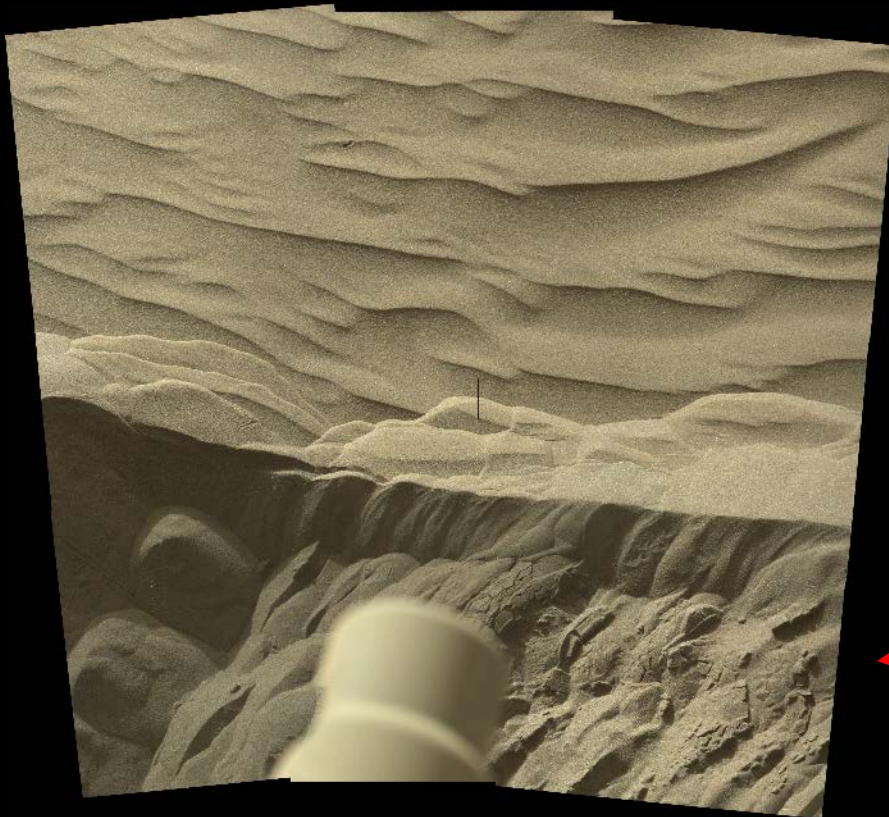




Sampling  
sand  
dunes

# Sand dunes on Mars named after Ralph Bagnold

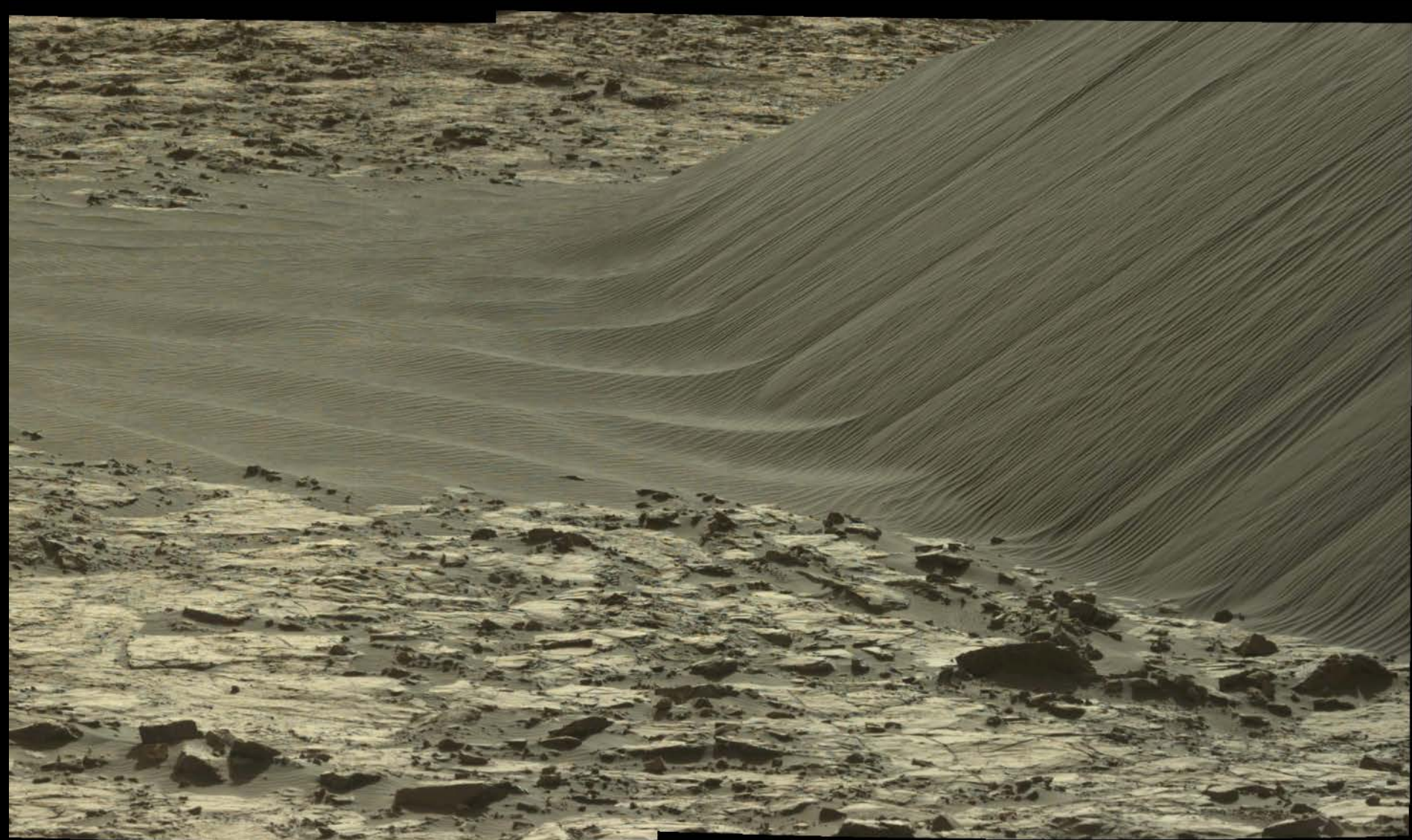
Bagnold making tracks in dunes on  
Earth 80 years ago



Our track on Mars!



**Ripple spacing on the sand dunes – different from the Earth because of low air pressure**



**The future - we are driving up an  
18,000-foot high mountain (Mt. Sharp)**



1 km

Murray Formation  
Bagnold Dunes

Hematite Unit

Clay Unit

Clay and Sulfate

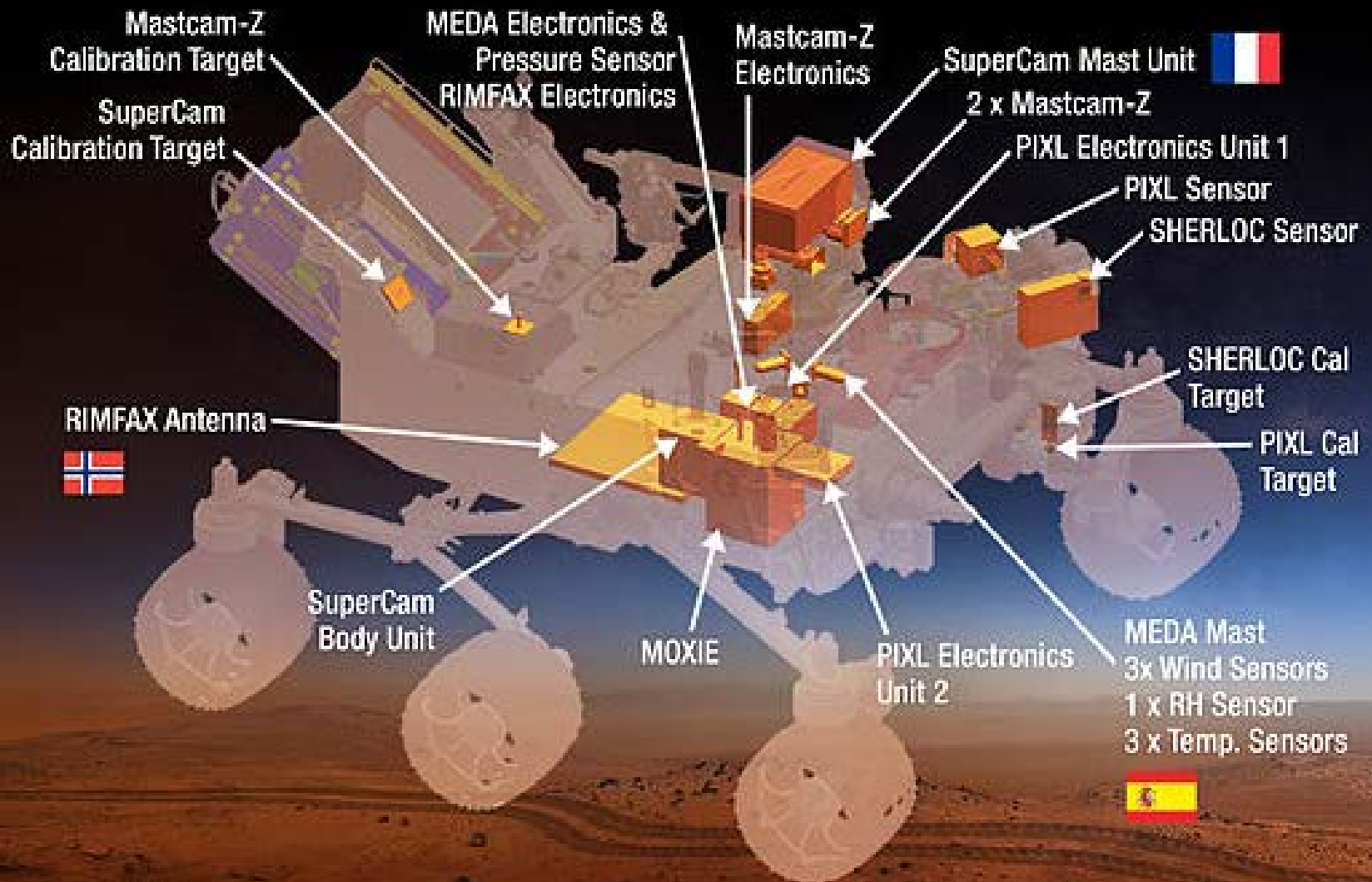
Sulfate Unit

Stream  
Channel

NASA/JPL-Caltech/MSSS

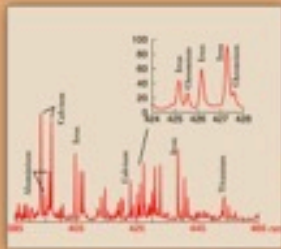


# Mars 2020 Rover

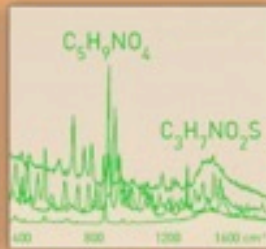


# SUPERCAM

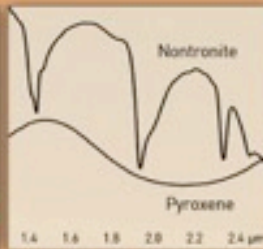
AN INSTRUMENT SUITE FOR THE MARS 2020 ROVER



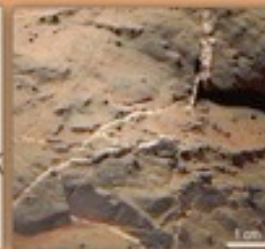
LIBS Capability



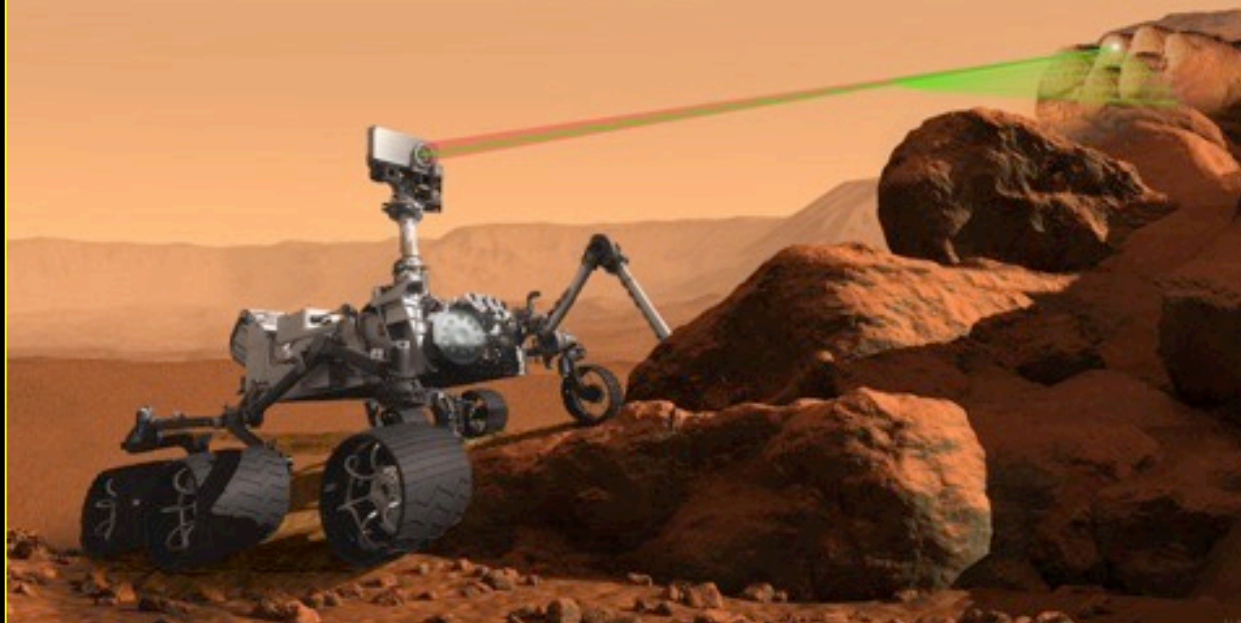
Raman & Time-resolved Fluorescence



VISIR Spectra



Color Micro Imaging



## 2020 Rover Plans:

- **Collect samples for future return to Earth**
- **Demonstrate production of oxygen for future astronauts**
- **Explore a new area of Mars**

Thank You For Your Attention!



## JSC/EC5 Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** Exploration of Mars with the ChemCam LIBS Instrument and the Curiosity Rover

**Date:** October 25, 2016

**Time:** 1:00 p.m. – 2:00 p.m.

**Location:** NESC Academy Online

**DAA 1676 Form #: 38006**

This is a link to the recording of the lecture material and questions and answers that resulted from that event <\\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY17 Knowledge Capture\20161025 SIPI Newsom MSL\1676 - Video>

### **Assessment of Export Control Applicability:**

This video of the presentation, along with the questions and answers, have been reviewed by the EC5 Spacesuit Knowledge Capture manager in collaboration with the author and are assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the NASA Engineering and Safety Center (NESC) Academy Online, the JSC Engineering Academy, and NASA Technical Library and Scientific and Technical Information (STI) Program for distribution through NASA's Technical Report Server (NTRS) (public or non-public) and YouTube viewing.

**Presenter:** Dr. Horton E. Newsom

**Synopsis:** The Mars Science Laboratory (MSL) Curiosity rover landed on Mars in August 2012, and has been exploring the planet ever since. Dr. Horton E. Newsom will discuss the MSL's design and main goal, which is to characterize past environments that may have been conducive to the evolution and sustainability of life. He will also discuss Curiosity's science payload, and remote sensing, analytical capabilities, and direct discoveries of the Chemistry & Camera (ChemCam) instrument, which is the first Laser Induced Breakdown Spectrometer (LIBS) to operate on another planetary surface and determine the chemistry of the rocks and soils.

**Biography:** Dr. Horton E. Newsom earned his undergraduate degree at the University of California Berkeley, and his doctorate at the University of Arizona, and is currently a senior research scientist and research professor within the Institute of Meteoritics and Department of Earth and Planetary Sciences at the University of New Mexico. He is a geologist and geochemist with more than 40 years of experience with planetary science, including the origin and composition of the Earth and Moon, and the study of terrestrial impact craters around the world and their hydrothermal systems. He has extensively studied surface processes on Mars including impact craters, sedimentary deposits, and phyllosilicate (clay) bearing terrains. He has also studied the origin and chemistry of Martian surficial materials using data from the Mars Odyssey Gamma Ray spectrometer experiment. Dr. Newsom has been involved with landing site selection for several Mars missions, including the Mars Exploration Rover (MER), Mars Science Laboratory (MSL), and future human landing sites. He is a co-investigator and science team member on the ChemCam Laser Induced Breakdown Spectroscopy (LIBS) instrument on the MSL

“Curiosity,” currently investigating habitable terrains on Mars. Dr. Newsom is actively involved with the daily operations of Curiosity, including planning science observations, and publication of the results. Dr. Newsom is also responsible for advisement of undergraduate, graduate, and postdoctoral student research, and has been extensively involved in NASA-funded educational outreach to K-12 teachers, and to local middle school and high school students, and Native American colleges.

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## “Exploration of Mars with the ChemCam LIBS Instrument and the Curiosity Rover”

### Questions Asked Outside the Knowledge Capture Event Real-Time Broadcast

No.	Question	Answer
1.	How is the baseline raster of known minerals protected from getting a layer of dust on it and thereafter having the data obtained (presumably for calibration) be altered by the reaction from the baseline raster plus the dust?	We discard the data from the first 5 Laser Induced Breakdown Spectrometer (LIBS) laser shots. The early shots often show evidence of dust. We have documented that the early shots also blow away the surface dust from around the LIBS pits. We have no evidence of any residual dust on calibration targets or most rocks after 5 shots. Shots on soils are different, as some soil grains from the surface can fall into the hole during the sequence.
2.	<p>Lunar dust has characteristics that result from the bombardment processes that create multifaceted sharp surfaces and shapes. Those have proved to be a problem in lunar exploration. Those dust grains stay in those shapes because there is no process that moves the dust on the Moon.</p> <p>Has the prevalent shape of sand and dust on Mars been established via detailed photography? Is erosion or grinding due to motion changing the shape of Mars dust to be more circular (and thus less of a problem)?</p>	The highest resolution imager on Mars Science Laboratory (MSL) is the Mars Hand Lens Imager (MAHLI) camera, but it cannot see very fine particles. For larger particles, we see both rounded particles and angular particles. This probably depends on how far they have been transported by water or wind. The surface regolith is much more Earth like than Moon like.
3.	Is it possible to predict inner parts of Mars using volcanic ash? I know on Earth we can find the core and mantle parts of Earth using earthquake waves (Seismic waves).	The relevant data are analyses of igneous rocks on Mars by the rovers, Martian meteorites, and the chemistry of the surface of Mars from the Odyssey Gamma Ray Spectrometer experiment. The Insight mission planned for 2018 will do the kind of seismometer measurements done on the Earth as well. Viking had seismometers that failed to record Martian Earthquakes. The available data have been used to infer that Mars has differentiated into a core, mantle, and crust.

No.	Question	Answer
4.	Based on the magnificent volcanoes on Mars; I would anticipate that layers of material are deposited due to volcanic eruptions. How are volcanic eruption layers discriminated from water flow based deposits? The same question related to layers deposited by dust storms.	There are meter-thick deposits on the volcanoes like Tharsis that are likely to be volcanic ash, which do not have the features of lava flows or fluvial deposits. Their chemistry from the Odyssey Gamma Ray instrument (GRS) is different from other areas and consistent with other volcanic deposits. These are not dust that has a distinctive composition measured by the Mars Exploration Rovers (MER) rovers and Curiosity. The rovers suggest that the deposits from airborne dust are extremely thin in the areas studied, millimeters at best. This finding is consistent with the GRS data that senses much more deeply, showing that the Mars regolith, down to one half meter depth, is not homogenized across the planet, while the dust probably is homogenized. The dust is stirred up by dust devils and rare dust storms.
5.	Due to Mars' lower gravity, the forces that act to create layers are different than on Earth. What are some of the results of deposits forming on Mars versus how similar deposits would form on Earth?	The effect of the gravity difference on layering is extremely small. For example the angle of repose of sand (e.g., sand dunes) is virtually the same on Earth and Mars, as frictional forces are so important. However, the low density of the atmosphere can affect the nature of ripples on dunes for example. Also, my research group is actively investigating the alluvial fans in Gale crater, which might have some subtle differences from terrestrial fans, with possibly thinner more sheet flood deposits, but we do not yet have an explanation. Most likely, it has to do with the sources of water when the fan formed before 3.2 billion years ago.